NASA

National Aeronautics and
Space Administration

August 24, 2001

NRA-01-OBPR-05

RESEARCH ANNOUNCEMENT

Materials Science: Ground-based Research Opportunities in Biomaterials and Radiation Shielding

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Notices of Intent Due: .... September 25, 2001
Proposals Due: .... November 27, 2001

OMB Approval No. 2700-0087

MATERIALS SCIENCE:
GROUND-BASED RESEARCH OPPORTUNITIES IN BIOMATERIALS AND RADIATION SHIELDING

NASA Research Announcement
Soliciting Ground-Based Research Proposals
for the Period Ending
November 27, 2001

NRA-01-OBPR-05
Issued: August 24, 2001

Physical Sciences Division
Office of Biological and Physical Research
National Aeronautics and Space Administration
Washington, D.C. 20546-0001

NASA RESEARCH ANNOUNCEMENT
MATERIALS SCIENCE: GROUND-BASED RESEARCH OPPORTUNITIES
IN BIOMATERIALS AND RADIATION SHIELDING

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NASA RESEARCH ANNOUNCEMENT

MATERIALS SCIENCE:
GROUND-BASED RESEARCH OPPORTUNITIES IN BIOMATERIALS AND RADIATION SHIELDING

This NASA Research Announcement (NRA) solicits proposals for ground-based experimental and theoretical research in materials science. The materials science discipline represents a broad range of research areas ranging from biomaterials, to metals and alloys, to radiation shielding materials. Descriptions of materials science research activities and interests are given in Appendix A. **For programmatic reasons, proposals will only be accepted for ground-based biomaterials and radiation shielding research relevant to NASA's mission. It is expected that a single solicitation for materials science and other Physical Sciences Division (PSD) disciplines will be released on an annual basis, starting in Fall 2001. All other relevant aspects of materials science research will be solicited at that time.**

Investigations selected for support as ground-based research under the Physical Sciences Division ground-based research program generally must propose again to a future solicitation in order to be selected for a flight opportunity.

Participation is open to U.S. investigators and to all categories of organizations: industry, educational institutions, other nonprofit organizations, NASA centers, and other U.S. Government agencies. **Since this NRA solicits only for ground-based research, proposals from non-U.S. investigators will not be accepted.** Proposals may be submitted at any time during the period ending November 27, 2001. Proposals will be evaluated by science peer reviews and engineering feasibility reviews. It is expected that awards will constitute either grants or cooperative agreements. Late proposals will be considered if it is in the best interest of the Government.

For the purposes of budget planning, we have assumed that the Physical Sciences Division will fund approximately 12 proposals for ground-based research in biomaterials. The level of award for biomaterials research is expected to be a maximum of $150,000 per year.

For the purposes of budget planning, we have assumed that the Physical Sciences Division will fund two team efforts in radiation shielding, one for radiation transport code development and one for radiation transport measurements and verification of radiation transport code accuracy.. These team efforts are expected to be supported at approximately $500,000 per year for four years. After appropriate non-advocate review for progress, cooperation and interaction with the other team, and timely reporting of data, the grants or cooperative agreements may be extended for up to another four years. If individual investigations are selected to supplement or complement team proposals, the total support for each of the two categories will be limited to $500,000 per year for four years. In addition to the two team efforts, the PSD will also support 1-3 individual investigators or teams via grants at a maximum of $150,000 per year for other aspects of radiation shielding research.

Appendices A and B provide technical and program information applicable only to this NRA. Appendix C contains general guidelines for the preparation of proposals solicited by an NRA.

This announcement will not comprise the only invitation to submit a proposal to NASA and is part of a planned sequence of solicitations inviting proposals in the disciplines of the physical sciences program.

NASA Research Announcement Identifier:	**NRA-01-OBPR-05**
NRA Release Date:	**August 24, 2001**
Notice of Intent Due:	**September 25, 2001**
Proposals Due:	**November 27, 2001**
Selection Announcement:	**May 2002**

This NRA is available electronically at **http://research.hq.nasa.gov/code_u/code_u.cfm**.. Notices of Intent and proposal cover page information should be submitted electronically via the Office of Biological and Physical Research Opportunities Web page at:

http://proposals.hq.nasa.gov/

If electronic means are not available, you may mail Notices of Intent to the address given below.
Submit Proposals to the following address:

Dr. Michael J. Wargo
c/o NASA Peer Review Services
Subject: NASA Research Proposal (NRA-01-OBPR-05)
500 E Street, S.W., Suite 200
Washington, D.C. 20024
Telephone number for delivery services: (202) 479-9030

NASA cannot receive deliveries on Saturdays, Sundays or federal holidays.

Proposal Copies Required:...............15

Investigators will be notified by electronic mail confirming receipt of proposal within approximately 10 working days after the proposal due date.

Obtain programmatic information about this NRA from:

Dr. Michael J. Wargo
Enterprise Scientist for Materials Science
Code UG
National Aeronautics and Space Administration
Washington DC 20546-0001
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Obtain additional reference information at the following address:

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Selecting Official:

Dr. Eugene H. Trinh, Director
Physical Sciences Division
Office of Biological and Physical Research
NASA Headquarters

Your interest and cooperation in participating in this effort are appreciated.

Kathie L. Olsen, Ph.D.
Chief Scientist and Acting Associate Administrator for the
Office of Biological and Physical Research

Appendix A
NRA 01-OBPR-05

TECHNICAL DESCRIPTION

MATERIALS SCIENCE: GROUND-BASED RESEARCH OPPORTUNITIES IN BIOMATERIALS AND RADIATION SHIELDING

I. INTRODUCTION

A. WHAT'S NEW FOR THIS RESEARCH ANNOUNCEMENT

The Office of Biological and Physical Research (OBPR), one of five National Aeronautics and Space Administration (NASA) strategic enterprises, conducts a program of basic and applied research using the reduced-gravity environment of space to improve the understanding of fundamental physical, chemical, and biological processes. The scope of the program, sponsored by the Physical Sciences Division (PSD), ranges from applied research into the effects of low gravity on the processing of various materials, to basic research that uses low gravity to create test conditions to probe the fundamental behavior of matter. This announcement is part of an ongoing effort to develop research in a specific scientific discipline, Materials Science.

The Division last released a NASA Research Announcement (NRA) for Microgravity Materials Science in 1998. It now expects to release NRAs supporting select topics in materials science research every year. **This announcement will emphasize two research areas of particular importance to NASA, biomaterials and radiation shielding.** Proposals in other areas of materials science will not be accepted. The Materials Science Program is in the process of being redefined. As a result of this redefinition, other research areas, including some of those currently supported, will be de-emphasized in subsequent NRAs.

NASA has supported research in microgravity materials science for over three decades. An extensive research program supports computational, theoretical and experimental investigations in ground-based laboratories. A number of investigations are conducted using materials science research apparatus built to take advantage of the limited low gravity test times available in ground-based facilities such as the drop-towers at the NASA Glenn Research Center, or NASA's parabolic low gravity flight research aircraft. These ground-based experiments, along with theoretical modeling, form the basis for most of our current understanding of the effects of gravity on materials processes and phenomena. While the materials science discipline has historically focused on research themes that benefit from access to long duration, high quality microgravity conditions, as the Microgravity Research Division evolved into the Physical Sciences Division, new tasks and research directions have been added that support NASA's crew health and safety responsibilities and NASA's exploration goals.

In the PSD program, ground-based research is used to gain a detailed understanding of the scientific questions associated with the phenomena of interest and to define experiments to be conducted in the extended low gravity test times available in spacecraft in low-Earth orbit. The ground-based research solicited in this announcement is expected to establish a foundation for future flight experiments in the areas of biomaterials and validation and verification of radiation transport models and codes.

This announcement is being released as the last in a series of a coordinated series of discipline-directed solicitations intended to span the range of the PSD program. PSD-supported solicitations are planned for annual release over the next several years. These annual research announcements will solicit for research in the following categories:

Biomolecular Systems
Biotechnology
Combustion Science
Fluid Physics
Fundamental Physics
Materials Science

B. RESEARCH ANNOUNCEMENT OBJECTIVES

This NRA has the objective of broadening and enhancing the PSD Materials Science Program, the goals of which are described in Section II, through the solicitation of:

1. Ground-based research that will establish the core of a biomaterials program comprised of three components: a) biomaterials research that is gravity dependent, i.e., research that would benefit from the unique advantages provided by long duration, high quality microgravity conditions; b) biomaterials research that supports NASA's unique responsibilities of crew health and safety; and c) biomaterials research that supports NASA's exploration goals. It is expected that the gravity dependent ground-based research would provide the foundation for future flight experiments.

2. Ground-based theoretical and experimental studies with an emphasis on radiation shielding research that would a) complete the measurement of required nuclear cross-sections, b) complete the development of radiation transport codes, c) experimentally test and verify the radiation transport codes and d) develop new radiation shielding materials that are either better than polyethylene or are multiple-use with performance better than/or approaching that of polyethylene.

Further programmatic objectives of this NRA include, for the specific research topics given in (1) and (2) above, objectives broadly emphasized by the civil space program, including: the advancement of economically significant technologies; technology infusion into the private sector; enhancement of the diversity of participation in the space program, public education, and outreach; and several objectives of specific importance to the physical sciences program. These latter objectives include the support of investigators in early stages of their careers, with the purpose of developing a community of established researchers for the International Space Station and other missions in the next 10-20 years, and the pursuit of research in microgravity that shows promise of contributing to economically significant advances in technology.

In support of the OBPR goal to "Use space research opportunities to improve academic achievement and the quality of life," individuals participating in the physical sciences program are encouraged to help foster the development of a scientifically informed and aware public. The physical sciences program represents an opportunity for NASA to enhance and broaden the public's understanding and appreciation of the value of research in the microgravity environment of space.. Therefore, all participants in this NRA are strongly encouraged to promote general scientific literacy and public understanding of the microgravity environment and materials science research conducted under microgravity conditions through formal and/or informal education opportunities. Where appropriate, supported investigators will be required to produce, in collaboration with NASA, a plan for communicating to the public the value and importance of their work.

C. DESCRIPTION OF THE ANNOUNCEMENT

With this NRA, NASA is soliciting proposals to conduct ground-based research in the areas of biomaterials and radiation shielding. At this time, NASA is not soliciting flight experiment proposals. Solicitation for flight investigations may resume with the issuance of the next NRA.

II. MATERIALS SCIENCE RESEARCH

A. INTRODUCTION

Materials science plays a key role in virtually all aspects of the nation's economy. While the ability to process materials to yield a given set of properties is clearly beneficial to humankind, the ability to produce a certain structure, and hence materials properties, is not yet at hand. Advances in materials science benefit a wide range of applications where materials are important, as well as other areas of research that depend on advances in materials science as a basis for their continued progress. Long-duration microgravity has been shown to be an important tool for establishing quantitative and predictive cause-and-effect relationships between the structure, processing, and properties of materials. Establishing, understanding and using these relationships are important elements in achieving increased international competitiveness.

The PSD Materials Science Program currently supports research in a broad range of areas that can be categorized in two orthogonal ways. The program has previously been described in terms of the class-like behavior of materials. Using this approach, the materials systems being investigated included biomaterials, electronic and photonic materials, glasses and ceramics, metals and alloys, and polymers and nonlinear optical materials. Alternatively, the Materials Science Discipline Working Group (DWG), an advisory body to NASA's Physical Sciences Division, has identified research areas, classified in terms of fundamental physical and chemical phenomena, that it believes would benefit from access to long-duration, high-quality microgravity conditions. Also included in the recommended research areas are those activities that the DWG believes are required to fully realize the potential of microgravity research (e.g., process modeling, materials characterization, etc.). The recommended research themes are: (1) Thermodynamics and kinetics of phase transformation; (2) Theory, modeling and experimental control of microstructure and defect formation; (3) Interfacial phenomena; and (4) Measurement of relevant material properties. The PSD has endorsed these recommendations.

In addition to these areas of Materials Science, research in areas that support the Office of Biological and Physical Research (OBPR) are a priority. Specifically, these are: radiation shielding appropriate for the International Space Station and long-duration lunar or Mars missions; biomaterials; and the effects of gravity on the materials processes necessary to convert resources found on other bodies of the solar system into usable commodities.

While the DWG has provided guidance for a broad program in materials science, this research announcement is focused on two particular sub-disciplines: biomaterials, which is in a nascent stage of development, and radiation shielding, which now has a clear set of goals and deliverables. The research topics that have been identified for inclusion in this announcement were obtained from recommendations provided by two sub-discipline specific workshops conducted in 2000. A Radiation Shielding Workshop was held at Lawrence Berkeley National Laboratory in August. The NASA Biomaterials Workshop was held jointly with the National Science Foundation U.S./Swiss Forum on NanoBioSciences at Princeton University in December. Members of the DWG participated in these workshops. **The DWG has noted that, particularly in the case of biomaterials, the research areas recommended by the workshop are commensurate with the research themes identified above for the full PSD Materials Science Program.**

B. GOALS OF THE OFFICE OF BIOLOGICAL AND PHYSICAL RESEARCH, THE PHYSICAL SCIENCES DIVISION, AND THE MATERIALS SCIENCE PROGRAM

The Physical Sciences Division Materials Science Program is part of NASA's Office of Biological and Physical Research (OBPR). The mission of OBPR is to use the synergy between physical, chemical, and biological research in space to acquire fundamental knowledge and generate applications for space travel and Earth applications. The goals that we strive to achieve in support of that mission are:

- Conduct research to enable safe and productive human habitation of space.
- Use the space environment as a laboratory to test the fundamental principles of physics, chemistry, and biology.
- Enable and promote commercial research in space.
- Use space research opportunities to improve academic achievement and the quality of life.

The goals of the Physical Sciences Division are:

- To carry out cutting-edge, peer-reviewed, and multi-disciplinary basic research as enabled by the space environment to address NASA's goal of advancing and communicating knowledge.
- To develop a rigorous, cross-disciplinary scientific capability, bridging physical sciences and biology to address NASA's human and robotic space exploration goals.
- To establish the ISS facilities as unique, on-orbit science laboratories addressing targeted scientific and technological issues of high significance.
- To enhance the knowledge base that contributes to Earth-based technological and industrial applications.

Materials science has a significant role to play in each of these goals, though OBPR's Goal 3 is principally the province of OBPR's Space Products Development Program.

Materials science deals with the relationships between the processing, structure, and properties of materials. The importance of materials processing lies in the understanding that the properties of most materials are dictated by the microstructure of the material, i.e., the morphology, size, spatial distribution, and chemical composition of the material's constituent phases, as well as internal defects. Thus, if the relationship between processing and microstructural development is well understood, then first-principles design of a material with desired properties can indeed be realized. This design of materials is occurring today to a limited extent by applying a fundamental understanding of materials at the atomic, molecular, mesoscopic, and macroscopic levels. Nevertheless, a fully predictive model of the relationships between processing techniques and the microstructure of a material remains an elusive goal. Microgravity offers a unique environment that can be used to extend our present understanding of materials processing in ways that are not possible in terrestrial laboratories.

Many of the techniques used to process materials are strongly influenced by the presence of a gravitational field. For example, during the formation of a solid phase from a fluid, as is the case during self assembly, crystal growth, and solidification, gravitationally driven convection of the fluid is probable. This fluid flow can alter the self-assembly process and spatial distribution of impurities in the liquid and resulting solid, induce structural defects in the crystal, and, due to the complexity of the flows which are possible, make the results of self assembly, crystal growth, and solidification experiments performed on Earth difficult to interpret. The presence of a gravitational field also can lead to sedimentation when two phases have different densities and at least one phase is a fluid. This sedimentation can lead to unwanted coagulation of the minority phase, as is the case during phase separation in certain polymer blends and in the colloidal processing of ceramics.

A microgravity environment thus offers new opportunities to develop a deeper understanding of the relationships between many materials processing techniques and the resultant microstructures and materials properties. As the magnitude of the gravitationally induced body force is much lower, the convective flow of fluids can be greatly reduced, thus permitting a more precise control of the phase transformation. In addition, gravitationally induced sedimentation, hydrostatic pressure, and deformation can be greatly reduced. Non-contacting forces such as those developed by acoustic, electromagnetic, and electrostatic fields can be used to position unconfined specimens and thus reduce the contamination of reactive melts. Finally, experiments performed in a microgravity environment will allow phenomena that are usually masked by the presence of gravity to be studied rigorously.

The Materials Science DWG's recommendation for the key elements of the supporting scientific knowledge base underpinning these process technologies are (listed in descending priority):

- Thermodynamics and kinetics of phase transformations (e.g., mechanisms of phase selection, oriented amorphous materials, and crystallization of amorphous materials)
- Theory, modeling and control of microstructure and defect formation (e.g., studies of morphological evolution, growth-induced defect formation, aerogels and foams, colloidal and sol-gel processing)
- Interfacial phenomena (e.g., wetting behavior, self-assembly mechanisms)

Along with the knowledge base, a database provided by the quantitative measurement of relevant thermophysical properties is of high priority. These data are of paramount importance for precise modeling and interpretation of experimental phenomena.

It should be noted that this list is not intended to be fully inclusive. Section C includes many more specific examples in the categories of interest to this solicitation, radiation shielding material and biomaterials. There are also topics sufficiently broad as to be included in all of the above categories. These include understanding the processes involved in producing novel materials and developing unique technologies supporting low-gravity experiments and practical aspects of materials processing. In addition, research in each of these broad categories is relevant to the program only insofar as microgravity is necessary for the successful completion of the research, or is in support of experiments performed in microgravity.

The objectives of the basic and applied research aspects of the materials science research program are:

- to advance the scientific understanding of materials processes affected by gravity,
- to use low-gravity experiments for insight into the basic mechanisms of materials processes,
- to provide the scientific knowledge needed to improve these processes,
- to contribute to the understanding and performance of Earth-based systems that depend on materials science, and
- to develop unique technologies specifically supporting low-gravity experiments and materials science.

For this solicitation, the above objectives are to be considered as applied to biomaterials and radiation shielding research.

C. AREAS OF RESEARCH RECOMMENDED BY THE MATERIALS SCIENCE DISCIPLINE WORKING GROUP, NASA BIOMATERIALS WORKSHOP, AND NASA RADIATION SHIELDING WORKSHOP

1. Biomaterials: Bioinspired and Bioderived Materials

There is no area of science, both inside and outside NASA, that is moving more rapidly than modern biology. While certain conventional biological structures are of direct interest to NASA, especially in its Fundamental Space Biology and Biotechnology Programs, biology offers an incredibly rich array of principles and examples that suggest materials-enabled approaches and non-biological analogs that are of unquestionable relevance to NASA's missions. One major opportunity is to mimic, in whatever materials and designs that are possible and appropriate, processes and structures already known in living systems. It will be decades before any mechanical system will truly mimic a living system, but there are countless opportunities short of full biomimicry. The concept of the "quasi-living, self-repairing, intelligent space ship" is one from science fiction, but in the concept there are details that may be invaluable in real systems. **Biological systems—systems with complexity substantially greater, and scales of size substantially smaller than any that NASA deals with—*self assemble*: an animal grows from a fertilized egg without the molecules being synthesized by man, and with the growth, differentiation, and specialization of cells taking place autonomously.**

The processing and synthesis of materials will also play an increasingly important role in the exploration of space. Specifically, the conservation and re-use of materials will be essential and hence will provide unique challenges. The deep exploration of space will require a philosophy of self-sustainable materials processing. This will be true in both microgravity conditions such as the Space Station and in the presence of significant gravitational forces, such as on Mars. This underlying technical philosophy is to be part of **an "ecosystem" approach to the conservation of materials** in regard to the fabrication of components for a wide range of needs (for example, structures, fuels, foods, and drugs). **Many of these approaches will be bioinspired and/or bioderived.** Biological systems represent small, specialized factories for the just-in-time production of requisite quantities of materials using techniques of separation, synthesis and assembly. NASA intends to capture and capitalize on this approach by the creation of new knowledge that will enable the development of engineered systems for long duration manned space flight where such systems are small, energy and mass efficient, and self-replicating.

Short-duration manned space travel in near-Earth orbit enjoys the relative security of a rapid return to comprehensive health care in the event of serious injury to onboard crew and staff. Similarly, the physiological effects of a low-gravity environment have thus far been mitigated by the fact that most U.S. space travel has kept crew and staff away from the effects of Earth's gravity for only short periods of time. Long-duration manned space travel, however, poses significant health and safety risks to crew and staff due to trauma and to long-term microgravity physiological effects. The success of long-duration manned spaceflight will demand that NASA not only understand the physiological processes and consequences of trauma and low-gravity phenomena but that it also develop viable, advanced biomaterials-based strategies for responding to these in the context of remote space travel where a rapid return to Earth is not possible.

Potential Approaches:

Almost every field of science studies processes that are in some sense self-assembling or self-organizing. Examples of processes that can be included under the rubric of self-assembly, and that illustrate systems of specific relevance to NASA, are:

a) Self-Healing Structures

The ability of a spacecraft to repair damage without external intervention is obviously of great interest, if it could be realized. Biological structures are all self-healing in a range of ways; there are, thus, many biological examples. **The question in science generally, and materials science specifically, is to understand the principles underlying these structures and processes, and to abstract these**

processes and apply them to systems of interest to NASA.

b) Robust, Redundant Systems

Again, biology provides examples. When a biological structure is damaged, other components can take the place of the damaged components or can change their function to take over for the damaged parts. The concept of designing systems that are based on the idea of adaptation and redundancy rather than on fail-safe methods would, if fruitful, dramatically change the range of options open to NASA systems architects.

c) Science Base for Self Assembly

The science base for self-assembly is in the early stages of its development, and NASA has an opportunity to play a major role in catalyzing the development of this field. **Due to its ubiquity, this science base is being forged in many physical sciences disciplines besides materials science.** In order to be comprehensive the examples below cover the full spectrum issues related to self-assembly. **However, this announcement seeks proposals in self-assembly that have explicit and direct relevance to biomaterials.**

Examples of areas of fundamental science that must be developed to convert self-assembly into a field that will supply concepts and prototypes to research engineers are these:

• <u>Coupled theory and experiment at all scales of sizes for self-assembling systems</u>
In broad terms, self-assembly can occur whenever there are competitive repulsive and attractive interactions between components. Understanding the physics of this competition and how gravity, or the absence of its effects, would influence various classes of systems is a core intellectual need in the field. Emphasis should be placed on biomaterials systems (e.g., bioinspired and bioderived).

• <u>Design of Self Assembling Systems</u>
The characteristics of a self-assembling system are very different from one designed for conventional fabrication: an automobile and a mouse are different; so are a microprocessor and a molecular crystal. A creative analysis of the characteristics of self-assembling systems, and understanding of how those characteristics might be embedded in new types of designs, would help to guide the utilization and development of self-assembly. The first examples of complex systems, for example, microcircuits and photonic band-gap materials, generated by designed self-assembly, are just beginning to appear. The acceleration of these types of demonstrations would do an enormous amount to focus attention on the field. One of the very attractive opportunities for self-assembly is to generate three-dimensional systems, and to break the tyranny of 2D photolithography. Self-assembly actually works *better* in 3D than in 2D, and thus complements photolithography, which works much better in 2D than in 3D. Emphasis should be placed on biomaterials systems (e.g., bioinspired and bioderived).

d) Gravitational Effects in Self Assembling Biomaterials Systems

Most self-assemblies are now carried out in systems in which the influence of gravity (which often overwhelms the relatively subtle interactions that are involved in self-assembly) is partially or completely annulled by suspension of components in an approximately isodense fluid medium. (In this sense, self-assembly is an area that is immediately suited for microgravity, since substantial effort must be invested at 1 g to remove the effects of gravity for most types of self-assembly involving systems that are not maintained in suspension by Brownian motion.) Understanding the interplay of gravity and other forces (electrostatic, van der Waals, surface tension, optically induced dipole-dipole, etc.) on self-assembling processes, and the role of the contrast in density between the objects being assembled and the medium in which self-assembly is occurring, are important needs in the field. This aspect of microgravity research in self-assembly is presently being vigorously pursued in the Fluid Physics discipline using colloids as the preferred materials system. There already exists a mature flight program. Proposals to this announcement in this area of self-assembly research should focus on gravitational effects in self-assembling biomaterials systems.

e) Materials Processing for System Enhancement/Repair

Materials processing for system enhancement or repair is a necessity for successful and prolonged space flight. For over 20 years, the preferred materials processing technique in space has been, of necessity, powder-based. In spite of the need to avoid particulate contamination and dispersal, powder processing allows maximum compactness of the processing operation with minimum energy requirements. The fabrication of structural components has the added constraint of generally low-Z materials for consideration of both fuel consumption and minimal secondary radiation production. Novel means of net shape part fabrication, materials toughening and self-repair will be necessary in the space environment and will benefit from the careful study of biological paradigms. The limited amount of payload on a space missions also requires that materials be multi-functional. An example would be zeolites, silicates with high internal surface areas that could be used as molecular sieves for gas separation and purification, as well as scaffolds for processes such as catalysis, and photosynthesis.

f) Fuel Systems

Materials play a central role in various fuel systems. Solar and nuclear powers are the most likely sources for extended space travel, e.g., a 1000+ day missions. Self-sustaining requirements provide a fundamental constraint to these well-established technologies. Although solar and nuclear power are the obvious candidates for extended travel, materials contributions to alternate fuel systems should also be considered at least for certain specialized applications. Emulation of the efficient, low-temperature, ATP-based energy conversion processes of biology represents a generational leap for human activity in space. Thermoelectric power generation can take advantage of substantial temperature gradients produced in deep space. The conversion of biomass for energy production might also be appropriate under certain conditions.

g) Biomaterials Approaches to Food Synthesis

While traditional food production has been considered relative to the constraints of an extended, extraterrestrial travel and habitation, synthetic food production might be necessary on extended missions. Such efforts would be expected to include bioinspired and/or bioderived approaches.

h) Biomaterials Research for Crew Health

Crew health presents special challenges in long space missions. Payload constraints would require that the drug inventory be both optimized and minimized. One approach would be to synthesize an appropriately wide range of drugs from a limited set of biorelevant building blocks. The “starting materials” could be either synthetic or natural.

The Physical Sciences Division supports tissue engineering research as part of its Biotechnology program. The nascent biomaterials area seeks to support research that supplements and complements current and emerging tissue engineering research through advanced materials approaches and concepts of synthesis and processing.

The emerging concepts of tissue engineering provide a clear path for NASA to develop a strategy concerning remote trauma and low-gravity effects to astronauts. Tissue engineering can exploit natural physiological processes to grow or regrow damaged tissue and organs. Tissue engineering can thus meet two essential NASA needs. One is the ability to control the physiological response to serious injury in space and the second is the ability to reproducibly create tissue to enable controlled studies of the effect of gravity, stress, convective flow, and hydrodynamics on physiological phenomena such as bone loss. These are activities that are fundamental to NASA’s Biotechnology program.

Scientific and commercial work to date in tissue engineering has been largely focused by specific clinical needs. Consequently, research and development has concentrated on the physiological outcomes of disease-specific tissue-engineering solutions. These applications involve different types of cells, different combinations of cells in varying spatial distributions, differing degrees of vascularization, and different pathways of signal transduction, among other issues.

Emphasis within the academic community has been focused on the *physiologic aspects* of tissue-engineering problems, despite the fact that tissue engineering is a *materials-intensive* technology. Relatively little research has explored the potentially rich interplay between materials synthesis and processing, structure, properties, and ultimately biological performance. As a consequence, there has been little directed effort to identify a common materials platform for tissue scaffolds. Such a platform requires that its chemistry, phase behavior, and three-dimensional topology to be flexibly controlled over length scales ranging from sub-molecular to macroscopic in order to guide the effective growth or regeneration of tissue systems.

NASA has the dual need to:

- Provide remote therapies in response to a range of serious traumas
- Create a means to controllably and reproducibly generate relevant tissues for Earth-based studies of low-g physiological effects

To meet this need, NASA's Materials Science Program seeks to identify the minimum set of materials, materials processing methodologies, and materials properties to create a single platform enabling remote and need-specific tissue scaffold manufacture and deployment. The long-term goal would be to develop a flexible and multifunctional materials platform that can be used as a controllable scaffold for the guided regeneration of a spectrum of different tissues and tissue systems. This amounts to a materials-driven, next-generation tissue engineering concept that transcends the current paradigm of disease-specific scaffold development.

The successful development of multifunctional tissue-scaffold constructs will almost certainly require teams of researchers with interdisciplinary expertise. The knowledge base must collectively span polymer synthesis, polymer processing, morphological and bio-relevant physical characterization, and *in vitro/in vivo* cell and tissue culture/assay. **Cell and tissue culture/assay are part of the PSD's Biotechnology program and research in these areas is not solicited for this NRA.**

However, while cross-disciplinary expertise from academic, industrial, and federal laboratories has been effectively combined to support and develop other polymer-based technologies - e.g., textiles, membranes, and composites - such teams have not yet emerged in the tissue engineering community. This is in great measure attributable to the lack of a common language between, on the one hand, the engineers and scientists expert in synthetic polymer systems and, on the other, the biologists and clinicians expert in natural proteins and cellular systems. An obvious immediate consequence of a NASA initiative in this area would be to develop the necessary teaming and cross-disciplinary symbiosis needed to meet a materials-enabled, next-generation tissue engineering challenge.

i) Advanced Sensor Development

NASA has a continuing need for low mass, low volume sensors with increased sensitivity and dynamic range that operate efficiently at low power and low maintenance. Applications include continuous health monitoring and diagnostics, environmental monitoring and materials failure assessment. Requirements are summarized below. Proposed research should focus on materials/biomaterials aspects of the science/technology.

Critical Parameters / Requirement	Examples, Means, Tools
as low water content as necessary	dry chemistry, microencapsulation, water in reverse micelles, hydration water bilayers
as low mass as necessary	self assembly

as low volume as necessary	Miniaturization, sensing single molecules, arrays
as low power as necessary	Biochemical energy conversion mechanisms in molecular motors
as high stability as necessary	Self-healing
as interference free as necessary	gravity independent, bio-inertness (blood contact)

<u>NASA Relevance for Biomaterials Research</u>

Biomaterials research that is relevant to NASA can be classified in three ways:

1. **Research that would benefit from access to long duration, high quality microgravity conditions**
2. **Research that supports NASA's unique responsibilities for crew health and safety**
3. **Research that supports NASA's exploration goals, for example through increases in reliability, autonomy, etc, and reductions in mass, power, volume, etc.**

Biomaterials proposals should include a section that clearly articulates the relevance of the research to NASA using at least one of the above criteria.

2. Radiation Shielding

Two of the principal goals of the Physical Sciences Division's radiation shielding program are to improve and experimentally test radiation transport codes needed to ensure crew safety on the International Space Station (ISS), and to develop a cost and mission effective radiation shielding material/concept to protect a crew for a one-year transit to/from and on the surface of Mars. A third objective is to develop practical multifunctional shielding materials and concepts that provide more effective radiation protection either from existing spacecraft components or from additional shielding, with less mass, which would reduce propulsion requirements. The provision of radiation shielding for a Mars mission or a Lunar base from the hazards of space radiation (galactic cosmic rays, GCRs, and solar energetic particles, SEPs) is a critical technology since crew safety depends on it and present estimates of deep-space radiation dose exceed present administrative limits applicable for low Earth orbit (LEO).

The use of presently available radiation transport codes with typical manned spacecraft shielding indicates that considerable mass will need to be added to Mars transit vehicles and surface habitats to limit radiation risk. This will impact propulsion requirements, mission scenarios, and mission costs. The effects of the GCRs and SEPs are not limited to interplanetary missions. Higher inclination orbits, such as that of the ISS, acquire a significant component of radiation dose from GCRs and SEPs at high geomagnetic latitudes. Estimates of dose from these sources have motivated the addition of supplemental shielding for ISS. Geosynchronous missions are effectively out of Earth's magnetosphere and exposed to the deep space radiation environment. More accurate radiation transport calculation methods and more effective shielding would be of significant benefit to a variety of NASA's missions.

a) Deep-Space Radiation Environment

The space radiation component that is most significant for radiation shielding requirements outside Earth's magnetosphere is Galactic Cosmic Rays. Their elemental composition, at the same energy per nucleon, is approximately 85% hydrogen nuclei (protons), 14% helium nuclei (alpha particles), and 1% heavy nuclei. The GCR flux contains all the elements with a predominance of the most stable nuclei such as hydrogen, helium, carbon, oxygen, neon, magnesium, silicon and iron. The median energy of the GCR is nearly 2 billion electron volts (2 GeV/nucleon). The cosmic ray flux extends many orders of magnitude above the median energy, with the flux rapidly decreasing as $E^{-1.7}$.. The spectra of the cosmic ray nuclei are modulated by solar activity at the lowest energies and the total GCR flux changes by about a factor of

2 over the solar cycle. The present models of the cosmic ray composition and energy spectra are considered accurate to better than 25% when projected into future solar cycles.

The flux of Solar Energetic Particles (SEP) ejected from active regions of the sun can increase by many orders of magnitude over times ranging from hours to days. Their composition varies from almost pure proton events to events with varied enhancements of helium and heavier nuclei. The energy spectra of individual events also vary but have much lower mean and maximum energies than the GCR. The timing of these events cannot at present be predicted, although historical data provide statistical information on maximum intensities, duration, and relationship to solar activity. Most solar energetic particles have energies low enough that they will decelerate and be stopped by ionization energy loss through interactions with atomic electrons. The presently available shielding codes are sufficiently accurate for ionization energy loss. The main SEP impacts are on extra-vehicular activity (EVA) and planetary surface operations, as long as spacecraft habitats are adequately shielded. However, the more stringent requirements for protection against GCR tend to predominate in their effect on mission cost.

b) Physical Processes in Radiation Shielding

The problem of shielding crew and equipment from the effects of GCR nuclei is dominated by the interaction of the GCR with the nuclei of the spacecraft shielding, since their nuclear interaction mean-free-paths generally are shorter than their range for slowing down and stopping by ionization energy loss. The interactions of GCR in shielding materials with subsequent particle decays and interactions involve all of the processes in nuclear and particle physics. Some of these processes can be neglected but the ones that produce the greatest energy losses by the primary particles and greatest energy deposition in materials must be included. The nuclear interactions typically break up, "fragment," both the incident GCR nuclei and the atomic nuclei of the shielding material. These fragments are: high energy fragments of the projectile nucleus (protons, helium, and other light nuclei), neutrons, and low energy fragments of the target nuclei. Some of the projectile's energy is lost in this process, but its fragments continue in approximately the same direction and with approximately the same velocity as the projectile. Thus, they can penetrate the shield to a greater depth if they do not suffer further nuclear interaction. When interacting in the shield, GCR protons also produce target fragments, but proceed through the shield with a significant fraction of their original energy. The target fragments have lower energies, though some of them can escape the shield. Heavy target fragments (nuclear evaporation products) have short ranges in the material with high ionization rates. The fragmentation process typically releases neutrons, except when both heavy projectile and target completely break up into very stable nuclei such as helium or carbon.

The projectile and target nuclei can break up into different sets of lighter nuclei. Their composition depends on whether the collision is central or grazing, the nuclear stability of the fragments, and (at projectile energies below about 3 GeV per nucleon) the nuclear structure of the projectile and target. Above 2 GeV per nucleon the fragmentation modes do not significantly vary with energy. The strongly interacting particles produced in the interactions in the shield (projectile fragments, neutrons, mesons) may undergo subsequent interactions (cascading) if their path length in the shield is sufficiently long. Neutrons are the most numerous particles to be found behind thick shielding for typical shielding materials. Neutrons, through inelastic and elastic collisions with nuclei of the shield material, undergo scattering; modeling their transport is a special problem. In materials containing large amounts of hydrogen (e.g., tissue), the scattering process produces slow protons that can contribute 20% or more of the dose equivalent.

Above GCR energies of a few hundred MeV/nucleon the nuclear interactions in the shield also result in the production of charged and neutral mesons, a process that increases very slowly with primary energy. The neutral mesons decay into gamma rays, which can initiate "electromagnetic" showers of gamma rays and electrons. This process may become important for thick shields, or those containing high atomic number elements. With increasing shielding depth the numbers of neutrons, secondary light ions, mesons, gamma rays and electrons build up, before slowly decreasing with depth as they interact again (or are absorbed).

The radiation transport codes must account for these processes in the complex shielding geometry and various materials of a spacecraft, as well as inside the body tissues of crewmembers. The codes must also include ionization energy loss of the charged particles, which is the mechanism that produces essentially all biological damage. The physical effects necessary to handle SEP shielding problems are taken into account by the requirements for accurate radiation transport codes.

c) Improvement of Radiation Transport Codes

Accurate radiation transport code(s) are one of the two main products sought by the Physical Sciences Division's radiation shielding research effort. The shielding codes must contain all the physical processes that are required to accurately predict the types and energy spectra of all significantly damaging particles as a function of depth in all relevant materials, including the body tissues of flight crews. The codes must be readily linked to GCR and SEP composition and spectra models and spacecraft shielding models that describe the geometry, material, and mass thickness of the spacecraft materials. The output of the codes (energy spectra and directions of ions and neutrons) must be easily linked to models of biological effects.

The transport codes that have most recently been examined for application to NASA mission designs are HZETRN, HETC, and FLUKA.

HZETRN (for high charge, Z, and energy, E, transport) is a one-dimensional deterministic method developed by NASA. It contains some of the most recent models for the interaction and fragmentation of GCR protons and heavy ions in shielding material. It has been used for shielding studies in evaluating effectiveness of various materials, including Lunar and Martian regolith. It has recently been applied to the ISS shielding problem. Since HZETRN is a one-dimensional code, widely scattered particles such as neutrons cannot be accurately modeled. Pi-meson transport is presently not incorporated.

The High Energy Transport Code (HETC) is a three-dimensional "Monte Carlo" method originally developed by DOE for calculating nucleon-meson transport. It has been used in concert with heavy ion and neutron transport codes for a number of space applications, including radiation dose and neutron flux in ISS and the study of secondary neutrons and charged particles behind deep Lunar regolith shields. The HETC is presently being improved for NASA applications. The improvements include the addition and coupling to HETC of heavy ion fragmentation models, incorporation of neutron production angle and transport methods, and an improved nucleon-meson transport method.

FLUKA (from FLUctuating Kaskade) was developed by CERN in Europe for particle physics experiment design. It is a three-dimensional (Monte Carlo) nucleon-meson transport method. FLUKA presently does not contain a heavy ion fragmentation model. In a current effort, a heavy ion interaction code (DTNUC) is being added to FLUKA. Work is also underway on an output format that would make FLUKA more suitable for NASA applications.

In addition to correcting the obvious deficiencies in the radiation transport codes, there are two other significant efforts that must be undertaken. The first is the determination of the accuracy of the codes in predicting the radiation that penetrates shielding material. This requires a set of measurements, initially with accelerator beam exposures in thick target "benchmark" tests, to compare with code predictions. The accuracy of the codes must finally be verified by comparison between code predictions and measurements behind thick shields in the cosmic ray flux. The second significant effort is to test and improve the models of heavy ion fragmentation that are presently used in the transport codes. The accuracy of these models can be partially determined by the thick-target benchmark comparisons with code predictions. Further error and sensitivity analyses of the codes will indicate what further improvements in the fragmentation models are necessary, and what cross section data is needed. Data on fragmentation cross-sections from thin-target measurements are presently incomplete, particularly in the energy region where nuclear binding energies affect fragmentation modes. Some thin target measurements and model improvements are in progress with concentration on neutron production.

d) Program Goals for Radiation Transport Code Development:

- Develop standard radiation transport codes for NASA radiation shielding engineering applications. The codes adopted as standard will be selected based on evaluation criteria that include accuracy, speed of calculation, efficiency in linking to shielding geometry and biological effects models, and code portability and maintainability. They must be applicable to multiple layers of materials of arbitrary composition and geometry. The calculations must yield identical results in spacecraft and laboratory geometries that can be compared with data obtained at particle accelerators and extrapolated to the space radiation environment. The output of different codes must be in an efficient format that allows significant comparisons and evaluations to be made among them and with experimental data.

- The accuracy of the codes is defined as the difference between the code predictions and the results of experimental measurements, relative to the results of the measurement. The accuracy goal for the codes is ±25%. The accuracy of the experimental measurements cannot be defined in a parallel manner; there is currently no knowledge of the true value of the measurement. That is what is sought. However, the experimental measurements should be made, and the data and experimental procedures analyzed, such that the precision and systematic error can reasonably be interpreted as ±25% accuracy or better. This precision and accuracy should hold, at the minimum, for measurements behind 30 g/cm^2 areal densities of aluminum, polyethylene, and copper (this corresponds approximately to the range of an iron nucleus with an energy of 850 MeV/nucleon and is a first approximation to the thickness of actual spacecraft shielding). This specification of accuracy and precision goals is provisional. They will be reviewed by a non-advocate panel during the next year and may be revised based on their findings.

- The quantities to be measured for comparison with the predictions of radiation transport codes are differential cross sections and particle yields.

  <u>Differential cross sections</u>, in this context, are the probabilities that one incident particle, of the type and energy found in GCR, will have a nuclear interaction with a single atomic nucleus of spacecraft or tissue material, resulting in at least one identified particle emitted into a defined direction with a measured energy. Cross sections are typically measured in a thin layer of a single material to ensure that only the result of a single interaction is observed.

  Inclusive differential cross sections are the probability of observing only some of the reaction products (while the unobserved products are lumped into an “inclusive” term in the description of the event).

  Exclusive differential cross sections give the probability of observing every component of the final state following the interaction.

  Differential cross sections are the fundamental quantities used by radiation transport calculations to compute the results of multiple interactions and changes in energy for each particle in the radiation field, as a function of depth in materials.

  Accuracies of differential cross sections, with respect to the presumed “true” value of the quantity, should be much better than the overall accuracy of validation tests.

  <u>Particle yields</u> are the numbers of particles emitted from a thick layer of material of known but arbitrary composition. They are the result of one or more interactions in the material and are generally expressed as the number of identified particles per unit area emitted in a given direction with a given energy (the “fluence spectrum") per unit incident fluence of nuclei, of the type and energy found in GCR.

  Particle yields test the predictions of radiation transport calculations.

  Particle yields are a function of the following experimental variables: incident particle mass, charge, energy, and direction; the emitted particle(s) mass, charge, energy, and direction; the charge and mass of the nuclei in exposed material, the material density; and, the depth in material at which the radiation field is considered.

  The validation of transport codes requires that the accuracy of their predictions be measured against particle fluences as a function of the range of available experimental variables.

- Equivalent dose, E, (in Sievert) is a calculated quantity related to the presumed risk incurred by human exposure to either the predicted or the measured radiation field.

  Since E is an integral quantity, radiation fields with different particle and energy compositions can average out to the same value of E.

  Integral quantities, like E, are not adequately rigorous tests of the ability of a radiation transport code to result in accurate predictions for radiation fields of composition different from the one being measured.

  However, accuracy in the value of E determined by the radiation transport code, relative to the value calculated from the measured fluence spectra, serves to assure that the maximum errors are bounded.

  Dose Equivalent is presently recognized by radiation protection organizations as a measure of biological risk and must be accurately calculated by the codes.

- The selected transport code or set of codes must be documented and an archival repository for maintenance and distribution of the codes developed.

e) Solicited Research Activities in Radiation Shielding

(1) Research to develop a standard code or set of codes for NASA applications

a) This research should incorporate development of a three-dimensional solution of the Boltzman equation for radiation transport (3-D version of HZETRN) and further improvements of the Monte Carlo methods HETC and FLUKA. In addition to work in code improvement, analysis of the remaining deficiencies of these three methods compared to needs for a standard NASA shielding code must be determined and plans, schedules, and costs to correct the foreseen deficiencies should be developed by the end of the first year of research. After the first year a non-advocate review of the results will be held to recommend future directions for the code improvements. Further work will be directed toward completing one or more of the codes for HEDS and in improvement toward the accuracy goals for the code(s).

b) During the first year of the code development work, error and sensitivity analyses are to be performed with the present HZETRN and HETC codes to determine the errors induced by uncertainties in fragmentation cross sections to the calculated particle spectra behind the shielding. These sensitivity and error analyses will be used to guide the priorities for measuring fragmentation cross-sections as described in (3) below.

c) The data from the cross sections measurement program, as described in 3. below must be compared with predictions of nuclear interaction and fragmentation models with a goal to improve the predictions of those models for cross sections that are not measured.

Proposals sought for this work may be from a consortium with in-depth expertise from each transport code method to be studied, or from individual investigator groups.

(2) Measurements and Verification of Radiation Transport Code Accuracy

Some initial accuracy assessments will be made with particle accelerator beams in thick target measurements as described in (3) below; final verification must be made in the cosmic ray flux. The verification may use high inclination space missions of opportunity, or a balloon borne deep space test bed described in (4) below. The present accuracy goals are defined in two ways: (a) the radiation dose in dose equivalent (Sieverts) as measured behind 30 g/cm^2 areal density of aluminum, and equivalent mass-thickness of polyethylene and copper**,** must be within ±25% of that predicted by the transport code; (b) the energy spectra of H, He, Ne, C, O, Mg, Si, Ca, Cr, Fe, and neutrons must be within ±25% of the spectra predicted by transport codes behind the shields listed above.

The particles and energy ranges to be measured will likely require multiple instruments and flights, so a coordinated measurement program should be described in each proposal, although an individual proposal may cover only part of the desired measurement.

(3) Measurement of Cosmic Ray Fragmentation Cross-Sections and Particle Spectra behind Shielding at Particle Accelerator Facilities

One objective of this work is to provide differential reaction cross sections of heavy nuclei fragmenting into lighter nuclei and neutrons in various thin targets, as needed to improve transport code accuracy. A second objective is to perform an initial assessment of transport code accuracy by performing several thick-target measurements (with targets in (2) above) with selected heavy nuclei projectiles, while measuring the spectra of the nuclei and neutrons behind the shielding. These measurements will use accelerator beams of protons through iron nuclei at energies between 0.1 and 2 GeV and must be prepared to measure:

a) The energy dependence of the projectile fragmentation into lighter nuclei, protons and neutrons on targets of aluminum, copper, and carbon.

b) Energy and angular dependence of differential cross sections for production of light ions and neutrons for selected heavy ion primaries on various thin target materials. Candidate beam particles for these measurements are shown in Figure 1 and Table 1 with a discussion of their selection following.

c) Measurement of energy spectra of ions and neutrons behind thick targets for selected heavy ion projectiles for assessment of transport code accuracy as in (2) above.

d) Exclusive cross sections for some final states to provide benchmarks for the Monte Carlo event generators used in HETC and FLUKA.

FIGURE 1: Measurements vs. LET

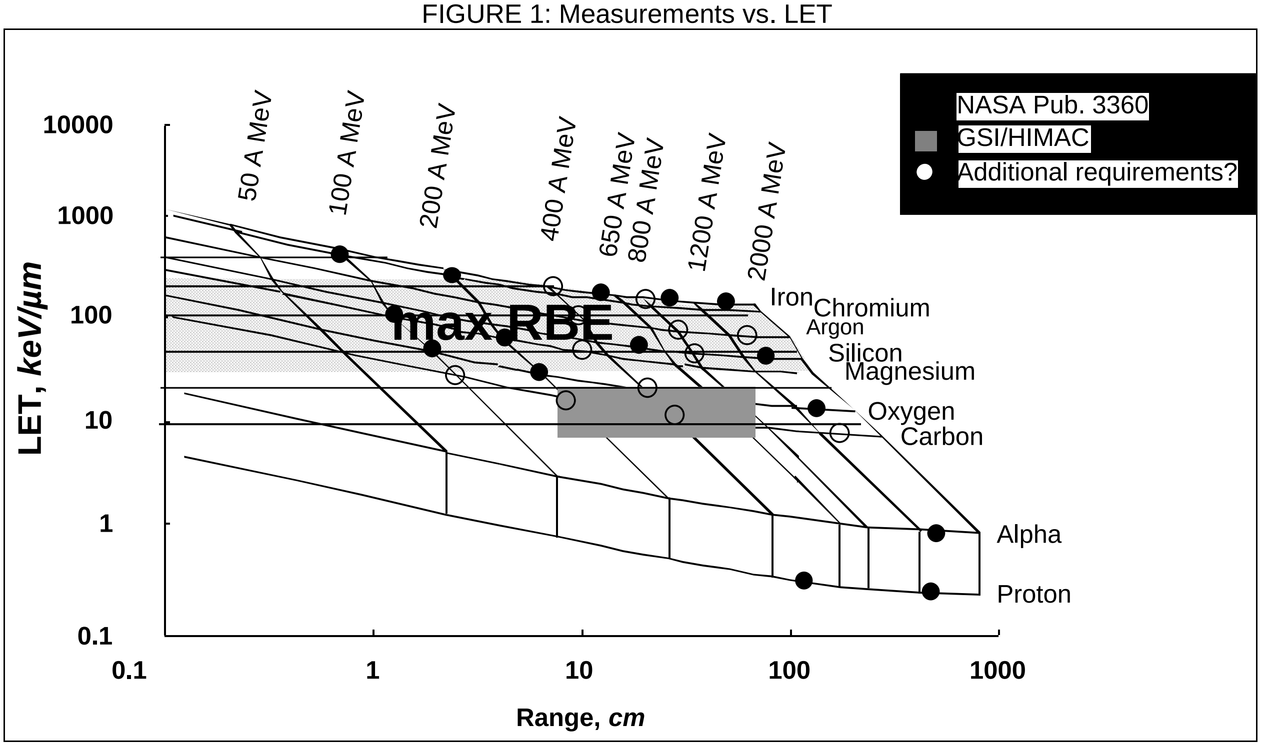

TABLE 1

ε_P	(Z,A)										
	H	He	C	N	O	Ne	Si	Ar	Ca	Mn	Fe
0.1		●	❍		●		●				●
0.2	●	●	❍ **X**	**X**	●**X**		●**X**	**X**			●**X**
0.4			❍		❍		❍	❍			❍
0.6		●			●	**X**	●**X**				●**X**
0.8							❍	❍			❍
1.0	●										●**X**
1.5		●	❍		●		●	❍	●	●?	●
2.0											❍

Appendix B of "Shielding Strategies for Human Space Exploration," J.W. Wilson J. Miller, A.Konradi, F.A. Cucinotta, Eds. NASA CP 3360 (1997) contains a matrix of cross sections that are recommended to be measured. Figure 1 shows these as data points on a plot of particle type and energy as a function of linear energy transfer (LET). Also shown is the region of maximum relative biological effectiveness (RBE), around an LET value of 100 keV/µm. This region is only sampled sparsely by the data points recommended for measurement in NASA CP 3360, which used physics criteria, more than biological criteria, to arrive at its conclusions. The open circles sample biologically significant particles and energies. In addition, since the above referenced work was published, some progress has been made in filling in the matrix, especially using carbon beams at the heavy ion accelerators in Darmstadt, Germany (GSI) and Chiba, Japan (HIMAC); these data are shown by shading along the carbon LET vs. range curve in Figure 1. The Lawrence Berkeley Radiation Shielding Workshop (2000) reviewed what has been accomplished and what still needs to be done. Some data points were added, in consideration of the need to match physical data with biological effect as a function of energy deposition and to improve understanding of particle production away from the beam axis. The revised matrix is shown in Table 1, above where, ε_p is the energy per particle (in GeV for protons and GeV/nucleon for others), (Z,A) denotes the particle species and the circles correspond to the data of Figure 1. The X-marks correspond to projectiles and energies where some, but not necessarily a complete set of data points exist (e.g., some targets, some angles). Table 1 indicates the range of accelerator beam ions and energies, which may be needed, depending upon the error and sensitivity analyses of the codes, and experimental measurements of the transport code accuracy.

Since the transport code accuracy is specified as ±25% for spectra behind thick shields, the cross sections may need to be measured to better accuracy. Information concerning required cross section measurements will be derived from the error and sensitivity analyses in solicited research activity (1) above and from thick target measurements as described in activity (2). Investigators should discuss the anticipated systematic and statistical accuracies they anticipate for various cross-section measurements.

The scope of the accelerator program is quite broad in the energies and number of ions (and neutrons) that may need to be measured. Several instruments will likely be needed, and measurements at accelerators in other countries may be needed in addition to measurements at the Brookhaven Booster Application Facility (BAF). A consortium or team proposal, or a coordinated set of individual proposals, will be needed to cover the range of measurements.

(4) Deep Space Test Bed Definition

Earth's magnetic field prevents the full energy spectrum of the GCR to reach the atmosphere except in the

Polar Regions. In the last ten years long duration circumpolar balloon flight experiments have become routinely available in the Antarctic, and occasionally available around the North Pole. These flights typically carry 1200 kg of apparatus to 3.5 millibars altitude (~3.5 g/cm^2) for about ten days. They offer relatively frequent, low cost opportunities for exposure to the cosmic ray environment. Proposals are invited for the definition of a test-bed to be flown on the circumpolar flights for experimental verification of transport codes, testing of new radiation shielding materials, and for testing new instrumentation (for neutrons, energy spectra behind shielding, dose). The definition should include an analysis of potential uses and users. The effects of the local radiation environment (cosmic rays, earth's albedo and interaction in the gondola) on potential uses should be evaluated. The definition effort should include a preliminary design for a gondola (structure), standard data system, standard monitoring system (temperatures, radiation environment, etc.). Concepts for example experiment accommodation should be included.

(5) Development of Novel Radiation Shielding Materials

Materials with the smallest mean atomic mass usually are the most efficient shields for the GCR. Except for physical properties and safety considerations, hydrogen would be the best shield. The reasons for this are not immediately apparent. They are related to the ratio of energy loss by ionization to fluence change by nuclear interactions. Both are related to the number of atoms of the material, per unit mass (in units such as grams), which is proportional to Avogadro's number divided by the atomic mass.

The energy loss by ionization of a single atom of shielding material is proportional to the number of electrons per atom and thus proportional to Z/A. However, the energy lost per gram of material and per incident fluence (e.g., in units of particles per cm^2), the "mass stopping power," is also inversely proportional to the density, ρ, (e.g., in g/cm^3) of the material, so that the energy lost by one incident particle per cm^2 per unit mass is proportional to $Z/\rho A$.

The number of nuclear interactions per unit mass and per unit incident fluence is proportional to σ/A, where σ is the total nuclear reaction cross section. To a first approximation, σ is proportional to $A^{2/3}$, so that the nuclear transmission is proportional to $1/A^{1/3}$. The ratio of electronic stopping power to nuclear interaction transmission is thus proportional to $Z/\rho A^{2/3}$.

Materials with small atomic mass have the highest number of electrons per nucleus (e.g., Z/A is 1 for hydrogen, 0.5 for carbon, but 0.48 for aluminum, 0.46 for iron, and 0.40 for lead). However, light mass materials have smaller nuclei and therefore can fit more of them into a given mass, so that there can be more nuclear interactions. However, the ratio of ionization energy loss to nuclear interactions is also dependent on the material density. For liquid hydrogen (ρ=0.07 g/cm^3), the ratio is ~14, whereas for aluminum (ρ=2.7 g/cm^3) the ratio is only 0.5, and for lead (ρ=11.3 g/cm^3) the ratio is 0.2.

It is clear from these considerations that a hypothetical shield consisting only of electrons and thick enough to ensure that a particle loses all its energy inside it (a thickness referred to as the "range" of the particle), would provide ideal shielding characteristics. A close second choice would be a hypothetical shield made of hydrogen, which has the highest ratio of electrons to nuclei per atom. However, while the range of an energetic iron nucleus with an energy of 1 GeV/nucleon (near the peak of the GCR energy spectrum) is approximately 30 cm in water (approximately 10 cm in aluminum), the range of a proton is 12 times greater and a shield intended to stop all particles up to iron would have to be equivalent to 300 cm of water of 100 cm of aluminum. Such thicknesses are not practical and nuclear reactions will always be a component of shielded radiation fields.

Slowing down incident GCR particles by ionization energy loss and avoiding nuclear interactions is not always an optimal strategy. As may be seen in Figure 1, slowing down nuclei such as carbon and oxygen, incident at high energy, makes them move to the left into the region of greater biological effectiveness. On the other hand, slowing down energetic nuclei such as iron, who are already beyond the peak biological effectiveness, makes them move to the left away from the region of high biological effectiveness.

Conversely, nuclear interactions that change a penetrating GCR nucleus into lighter pieces, e.g., nuclear interactions that fragment silicon into carbon and helium-4 (alpha particles) pieces result in particles of lower biological effectiveness, while the fragmentation of iron into chromium or silicon fragments would result in a more effective secondary radiation field.

The character of these interactions is also important. Lighter nuclei have fewer neutrons to release and some nuclei, e.g., carbon, can break into three helium nuclei without releasing any neutrons. For very thick shields, lighter nuclei are also more effective in shielding against the build up neutrons.

Detailed transport calculations performed using HZETRN, which include the actual GCR particle spectra, have demonstrated the net effectiveness of hydrogen-rich composites and other low-mass shielding materials. The shielding effectiveness is not strictly monotonic with mean atomic mass because of different fragmentation modes and neutrons release, but compounds containing light nuclei and hydrogen, such as polyethylene and lithium hydride, are presently considered among the most effective GCR shields. Polyethylene has been applied for local shielding on the ISS and lithium hydride as been studies in the past for space nuclear reactor shielding.

A recent workshop considered the possibilities for novel shielding materials and recommended that compounds and absorbing materials containing high atomic ratios of hydrogen be examined for possible HEDS application. These included carbon nanomaterials, metal hydrides, and palladium/silver alloys. Some of these materials are already under study by groups examining renewable and clean energy sources. In the development of novel shielding materials factors such as mechanical and other properties enabling multiple functions, possible hazards and their mitigation, potential ease of manufacture/fabrication and costs must be considered. Some materials that are not optimum for shielding alone may have a multiple function such as high strength, or hydrogen storage. Materials which are considered for shielding must be evaluated for their effectiveness, first using the radiation transport codes, and then by measurement at particle accelerators and with the Deep Space Test Bed. New materials without other functions must be compared with polyethylene as a minimum standard of shielding performance. Multifunctional materials must permit substitution for a known spacecraft material and have shielding effectiveness approaching or exceeding polyethylene.

(6) Radiation Shielding with In Situ Materials

Shielding for surface habitats may use planetary regolith material either in raw form or processed for use as a construction material. Efforts are underway to evaluate the radiation shielding effectiveness of Martian regolith of standard surface composition, and regolith strengthened with epoxy. This work includes measurements of fragmentation cross-sections in the more abundant regolith elements, improvement of fragmentation models, and tests of transport codes with these materials. Fabrication methods for epoxy-regolith composites will be evaluated, and these composites will be tested at accelerators.

<u>Coordination of NASA Radiation Transport Code Development and Radiation Transport Measurements</u>

The development of a documented and verified radiation transport code system for NASA requires a variety of research tasks involving code development, nuclear and particle theory, measurements at particle accelerators, and measurements in the cosmic ray flux. Teams and individual researchers selected in this NRA will need to coordinate research activities and findings in order to bring this activity to a successful conclusion for NASA. To this end, NASA will coordinate an initial meeting with investigators selected for funding and subsequent program reviews to foster and ensure coordination and cooperation.

It is expected that the process will proceed essentially as follows. Proposal content and schedule should reflect the following sequence or indicate in a substantial manner why it should not be followed. First, known deficiencies in the transport codes must be corrected, including major additions and revisions in the present candidates. Initial assessment of code differences by comparison of bench-mark calculation results are expected to indicate the direction of these efforts.

The initial measurement of code accuracy will involve comparison between code predictions and experimental measurements using several beam nuclei and energies and “thick” target materials. Measurement of the variety of particles produced by interaction and cascading in the thick shields (particles lighter than the beam, target particles, and neutrons, with large energy ranges) will require a variety of instrumentation and techniques. A coordinated program between code development groups and experimental groups will be required to make this activity productive.

These “benchmark” comparisons between measurements and calculations may identify further features that may be needed in the codes, or improvement in the fragmentation and particle production models in the codes. Subsequent error and sensitivity analyses with the codes may identify with more precision the features that need improving in the codes and the interaction models.

The present heavy ion fragmentation models are known to be incomplete in describing all nuclear interaction phenomena at lower energies, particularly concerning neutron production. Experimental data to determine the accuracy of these models, and to guide the improvements of the models, are also sparse. Measurements with a variety of beam nuclei, energies, and thin target materials are expected to be required to improve and test the models. The measurements to be performed cover a wide range of produced particles, energies and their angles. As a result, a variety of experimental techniques will be needed. This will require close cooperation between the measurement team and the model and code development team to develop an efficient process. Verification of transport code accuracy within shielding in the cosmic ray flux will require close coordination between the code development teams and the experimental teams to insure adequate instrumentation and interpretation of the results. The iteration of some of these steps in the development process may be necessary. Finally, the documentation of the codes will require a concerted effort by all teams involved.

III. PROPOSAL SUBMISSION INFORMATION

This section gives the requirements for submission of proposals in response to this announcement and, in the event of conflict, these requirements take precedence over instructions appearing in Appendix C. The research project described in the typical proposal submitted under this announcement must be directed by a Principal Investigator who is responsible for all research activities and may include one or more Co-Investigators. Investigators must address all the relevant selection criteria in their proposal as described in Section VII of this Appendix and must format their proposal as described in this section. Additional general information for submission of proposals in response to NASA Research Announcements may be found in Appendix C.

A. NOTICE OF INTENT

Organizations planning to submit a proposal in response to this NRA should notify NASA of their intent to propose by electronically sending a Notice of Intent (NOI) via the OBPR Opportunities Web page:

http://proposals.hq.nasa.gov/

If electronic means are not available, you may mail Notices of Intent to the address given for proposal submission in the following section, or Facsimile transmission is acceptable; the PSD fax number is (202) 358-3091.

The Notice of Intent, which should not exceed two pages in length, must be typewritten in English and must include the following information:

- The potential Principal Investigator (PI), position, organization, address, telephone, fax, and e-mail address
- A list of potential Co-Investigators (Co-Is), positions, and organizations
- General scientific/technical objectives of the research
- The equipment of interest listed in this NRA, if appropriate

The Notice of Intent should be received at NASA Headquarters not later than 4:30 pm EST, September 25, 2001. The Notice of Intent is being requested for informational and planning purposes only, and is not binding on the signatories. Institutional authorizations are not required. The Notice of Intent allows NASA to better match expertise in the composition of peer review panels with the response from this solicitation. In the Notice of Intent, investigators may request more detail on the capabilities of the specific equipment (Appendix B) that might be used to accomplish their scientific objectives and/or items listed in the Bibliography (Appendix A, Section VIII).

B. PROPOSALS

The proposal should not exceed 20 pages in length, exclusive of appendices and supplementary material, and should be typed on 8-1/2 x 11-inch paper with a 10- or 12-point font. Extensive appendices and ring-bound proposals are discouraged. Reprints and preprints of relevant work will be forwarded to the reviewers if submitted as attachments to the proposal.

The guidance in Appendix C, Section d regarding the content of renewal proposals is not applicable to this NRA. Proposals should not rely on references to previous proposals for any information required for a complete proposal.

IV. <u>WHAT'S DIFFERENT ABOUT THE PROPOSAL PREPARATION PROCEDURES FOR THIS NRA?</u>

<u>ALL APPLICANTS</u> to this research announcement are expected to use SYS-EYFUS, the NASA Internet-based proposal management system to submit a non-binding notice of intent and the required new proposal summary information. Information about SYS-EYFUS, and obtaining access to and the use of this system is available in Appendix E.

It is particularly important that Investigators who seek to extend an existing NASA research activity that is relevant to this NRA must submit proposals that clearly identify and document achievements on their current effort and how it supports their request for additional sponsorship. Such follow-on proposals will be reviewed on an equal basis with all other submitted proposals.

To ensure consistent assessment of budgets, investigators must use the budget forms provided.

The same budgetary detail must be provided for all subawards as that provided for the Principal Investigator and home institution.

Investigators should include in the budget a request for travel funds to support attendance at each PSD Materials Science Conference that will be held during the grant period of performance. For planning purposes, PSD Science Conferences are scheduled for the summers of 2004, 2006, and 2008.

Fifteen copies of the proposal must be received at NASA Headquarters by November 27, 2001, not later than 4:30 PM EST. Treatment of late proposals is described in Appendix C. Send proposals to the following address:

> **Dr. Michael J. Wargo**
> **c/o NASA Peer Review Services**
> **Subject: NASA Research Proposal (NRA-01-OBPR-05)**
> **500 E Street, S.W., Suite 200**
> **Washington, D.C. 20024**
> **Telephone number for delivery services: (202) 479-9030**

NASA cannot receive deliveries on Saturdays, Sundays or federal holidays.

Proposals submitted in response to this Announcement must be typewritten in English and contain at least the following elements (in addition to the required information given in Appendix C) in the format shown below. The proposal should be assembled in the following order:

1. Proposal cover pages, which includes investigator and proposal information and proposal abstract
2. Table of Contents
3. Research Project Description containing the following elements:
   - Statement of the hypothesis, objective, and value of this research
   - Review of relevant research
   - Justification of the need for low gravity to meet the objectives of the experiment
   - Description of the diagnostic measurements that would be required to satisfy the scientific objectives of any proposed low gravity experiments
   - Estimation of time profile of reduced-gravity levels needed for the experiment or series of experiments
   - A clear and unambiguous justification of the need to perform the experiment in ground-based reduced-gravity facilities

- A clear and concise description of the education and outreach activities, not to exceed 5% of the budget. Proposed K-12 related education activities should adhere to and identify relevant education standards.
- A description of a ground-based testing program that might be needed to define future space flight experiment requirements in terms of experiment conditions, acceleration levels and durations, control and diagnostic measurement requirements, etc.
- Management plan appropriate for the scope and size of the proposed project, describing the roles and responsibilities of the participants

4. Prior Period of Support
   For follow-on proposals of ongoing PSD-sponsored projects, a summary of the objective and accomplishments of the prior period of support, including citations to published papers derived from the existing tasks, must be included as part of the investigator's justification for continued support.
5. Appendices:
   - Budget Justification Page: supplementary budget information and budget explanations. The information desired is explained below.
   - Summary of current and pending support for the Principal Investigator and Co-Investigators
   - Complete current curriculum vita for the Principal and Co-Investigators, listing education, publications, and other relevant information necessary to assess the experience and capabilities of the senior participants
6. Proposal Cost Detail Desired.. Sufficient proposal cost detail and supporting information will facilitate a speedy evaluation and award. Dollar amounts proposed with no explanation (e.g., Equipment: $58,000, or Labor: $10,000) may cause delays in evaluation or award. The proposed costing information should be sufficiently detailed to allow the Government to identify cost elements for evaluation purposes. Generally, the Government will evaluate cost as to reasonableness, allowability, and allocability. Enclose explanatory information, as needed. Each category should be explained. Offerors should exercise prudent judgment as the amount of detail necessary varies with the complexity of the proposal.
7. 3.5 inch computer diskette containing electronic copy of Principal Investigator's name, address, complete project title, and executive summary

V. NRA FUNDING

Funds are not currently available for awards under this NRA. The Government's obligation to make award(s) is contingent upon the availability of appropriated funds from which payment can be made and the receipt of proposals that NASA determines are acceptable for award under this NRA.

For the purposes of budget planning, we have assumed that the Physical Sciences Division will fund approximately 12 proposals for ground-based research in biomaterials. The level of award for biomaterials research is expected to be a maximum of $150,000 per year.

For the purposes of budget planning, we have assumed that the Physical Sciences Division will fund two team efforts in radiation shielding, one for radiation transport code development and one for radiation transport measurements and verification of radiation transport code accuracy. These team efforts are expected to be supported at approximately $500,000 per year for four years. After appropriate non-advocate review for progress, cooperation, and interaction with the other team, and timely reporting of data, the grants or cooperative agreements may be extended for up to another four years. If individual investigations are selected to supplement or complement team proposals, the total support for each of the two categories will be limited to $500,000 per year for four years. In addition to the two team efforts, the PSD will also support 1-3 individual investigators or teams via grants at a maximum of $150,000 per year for other aspects of radiation shielding research.

It is particularly important that the investigator realistically forecast the projected spending timeline rather than merely assuming an equal amount (adjusted for inflation) of requirements for each year. Specifically, the resources required for the first year should not be overestimated. The proposed budget for ground-based studies should include researcher's salary, travel to science and NASA meetings, other expenses (publication costs, computing or workstation costs), burdens, and overhead. During subsequent years, NRAs similar to this NRA will be issued, and funds are planned to be available for additional investigations.

VI. GUIDELINES FOR INTERNATIONAL PARTICIPATION

NASA accepts proposals for flight experiments from all countries, although this program does not financially support Principal Investigators in countries other than the U.S. **Since flight experiments are not being solicited by this Announcement, non-U.S. proposals will not be accepted.** Proposals from U.S. institutions involving collaborative research efforts with foreign entities are permitted.

VII. EVALUATION AND SELECTION

A. EVALUATION PROCESS

The evaluation process for this NRA will be based on a peer review of the proposal's intrinsic scientific and technical merit, articulated relevance to the microgravity program, and cost of the research plan. The reviewers will be scientific and technical experts from government, academia, and industry. Each proposal will be reviewed independently by members of the review panel and discussed at a review panel meeting to determine a consensus evaluation for the proposal. All proposals will be evaluated on a merit scale of 1 (worst rating) to 9 (best rating). A rating below 5 is not generally considered for funding. NASA will also conduct an internal engineering review of the potential hardware requirements for proposals that propose the development of a deep space test bed and/or radiation transport code testing and verification in the GCR flux. The external peer review and internal engineering review panels will be coordinated by the NASA Enterprise Scientist for Materials Science. Consideration of the programmatic objectives of this NRA, as discussed in the introduction to this Appendix, will be applied by NASA to ensure enhancement of program breadth, balance, and diversity; NASA will also consider the cost of the proposal. The PSD Director will make the final selection based on science panel and programmatic recommendations. Upon completion of all deliberations, a selection statement will be released notifying each proposer of proposal selection or rejection. Offerors whose proposals are declined will have the opportunity of a verbal debriefing with a NASA representative regarding the reasons for this decision. Additional information on the evaluation and selection process is given in Appendix C.

B. EVALUATION FACTORS

The following section replaces Section (i) of Appendix C. The principal elements considered in the evaluation of proposals solicited by this NRA are relevance to NASA's objectives, intrinsic merit, and cost. Of these, intrinsic merit has the greatest weight, followed by relevance to NASA's objectives, which has slightly lesser weight. Both of these elements have greater weight than cost. Evaluation of the cost of a proposed effort may include the realism and reasonableness of the proposed cost and available funds. Evaluation of the intrinsic merit of the proposal includes consideration of the following factors, in descending order of importance:

1. Overall scientific or technical merit, including evidence of unique or innovative methods, approaches, or concepts, the potential for new discoveries or understanding, or delivery of new technologies/products and associated schedules;
2. Qualifications, capabilities, and experience of the proposed Principal Investigator, team leader, or key personnel who are critical in achieving the proposal objectives;
3. Institutional resources and experience that are critical in achieving the proposal objectives;
4. Proposed plan for education and public outreach activities. Examples include such items as involvement of students in the research activities, technology transfer plans, public information programs that will inform the general public of the benefits being gained from the research, and/or plans for incorporation of scientific results obtained into educational curricula including compliance with relevant education standards.

5. Overall standing among similar proposals available for evaluation and/or evaluation against the known state of the art.

The following questions should be kept in mind by Investigators when addressing the relevance to NASA's scientific and programmatic objectives:

1. Is microgravity of fundamental importance to the proposed study, either in terms of unmasking effects hidden under normal gravity conditions or in terms of using gravity level as an added independent parameter?
2. Do the issues addressed by the research have the potential to close major gaps in the understanding of fundamentals of materials science processes?
3. Is there potential for elucidation of previously unknown phenomena?
4. Is the project likely to have significant benefits/applications to ground-based as well as space-based operations involving materials processes?
5. Are the results likely to be broadly useful, leading to further theoretical or experimental studies?
6. Can another project in the specific sub-area be justified in terms of limited resource allocation?
7. Is the project technologically feasible, without requirements for substantial new technological advances?
8. How will this project stimulate research and education in the materials science area?
9. Is the cost of the proposed effort realistic and reasonable?
10. How does the projected cost/benefit ratio compare with other projects competing for the same resources?
11. What is the potential of this project in terms of stimulating future technological "spin-offs"?
12. Are there strong, well-defined linkages between the research and OBPR goals? (See Section IIB of this Appendix.)

C. SELECTION CATEGORIES, PERIOD OF SUPPORT

Proposals selected for support through this NRA will be selected as ground-based investigations. Investigators offered support in the ground-based program normally will be required to submit a new proposal for competitive renewal after at most four years of support.

The selected investigations will be required to comply with PSD policies, including the return of all appropriate information for inclusion in the PSD archives during the performance of and at the completion of the contract or grant.

VIII. BIBLIOGRAPHY

Background materials are available to NRA investigators upon written request to:

Dr. Donald C. Gillies
SD 46
Space Sciences Laboratory
Marshall Space Flight Center
National Aeronautics and Space Administration
Marshall Space Flight Center, AL 35812-0001
(256) 544-9302

Documents and Web sites that may provide useful information to Investigators are listed below:

1. Office of Biological and Physical Research Homepage at NASA Headquarters, http://spaceresearch.nasa.gov

2. Microgravity Research Program Office Homepage at NASA Marshall Space Flight Center, http://microgravity.msfc.nasa.gov

3. NASA Microgravity Materials Science Conference 2000 Proceedings, NASA Conference Proceedings CP-2001-210827, March 2001.

4. Third Microgravity Material s Science Conference Extended Abstracts, http://www.ssl.msfc.nasa.gov/colloquia/mmsm/oralpresentations.html

5. Microgravity Science and Applications Program Tasks and Bibliography, 2000, (and prior editions) http://peer1.idi.usra.edu/peer_review/taskbook/taskbook.html

Appendix B
NRA 01-OBPR-05

HARDWARE AND FACILITIES DESCRIPTIONS

I. GROUND-BASED FACILITIES

Investigators often need to conduct reduced gravity experiments in ground-based facilities during the experiment definition and technology development phases. The NASA ground-based reduced-gravity research facilities that support the PSD Materials Science Program include an array of specialized laboratory apparatus, such as laboratory equipment (i.e., furnace systems, special diagnostic tools and equipment, etc.), an evacuated drop tube at MSFC, a drop tower at GRC, and parabolic flight research aircraft. A variety of specialized test apparatus have been constructed and used to conduct a wide range of materials science research. In general, these apparatus have been developed to accommodate specific individual investigator's requirements. In addition, other hardware and facilities have been developed which have the potential for use by investigators. Investigators should denote any additional facilities needed for their research, and such facilities, if available, can be made accessible on a limited basis.

A. 5.18-SECOND ZERO GRAVITY FACILITY

The 5.18-Second Zero-Gravity Facility has a 132-meter free-fall distance in a drop chamber, which is evacuated by a series of pumpdown procedures to a final pressure of 1 Pa. Experiments with hardware weighing up to 450 kilograms are mounted in a one-meter diameter by 3.4-meter high drop bus. Residual acceleration of less than 10^{-5} g is obtained. At the end of the drop, the bus is decelerated in a 6.1-meter deep container filled with small pellets of expanded polystyrene. The deceleration rate is typically 60 g (for 20 milliseconds). Visual data is acquired through the use of high-speed motion picture cameras. Also, other data such as pressures, temperatures, and accelerations are either recorded on board with various data acquisition systems or are transmitted to a control room by a telemetry system capable of transmitting 18 channels of continuous data. Due to the complexity of drop chamber operations and time required for pump-down of the drop chamber, typically only one test is performed per day

B. PARABOLIC FLIGHT RESEARCH AIRCRAFT

The aircraft can provide up to 40 periods of low gravity for 22-second intervals each during one flight.. The aircraft accommodates a variety of experiments and is often used to refine spaceflight experiment equipment and techniques and to train crew members in experiment procedures, thus giving investigators and crew members valuable experience working in a low gravity environment. Qualified observers or operators may fly with their experiment packages. The aircraft obtains a low-gravity environment by flying a parabolic trajectory. Forces twice those of normal gravity occur during the initial and final portions of the trajectory, while the brief pushover at the top of the parabola produces less than one percent of Earth's gravity (10^{-2} g). The dimensions of the interior of the aircraft bay are approximately three meters wide and two meters high by 16 meters long. Several experiments, including a combination of attached and free-floated hardware (which can provide effective gravity levels of nominally 10^{-3} g for periods up to 10 seconds) can be integrated in a single flight. The aircraft can supply a total of 80 amps of 28-volt dc, 90 amps of 115-volt ac, 60 Hz and 30 amps open each phase of 3-phase 115-volt ac 400 Hz. These are maximum powers available to all users. Instrumentation and data collection capabilities must be contained in the experiment packages.

C. LOW GRAVITY AIRCRAFT MATERIALS SCIENCE APPARATUS

1. Automated Directional Solidification Furnace (ADSF)

This furnace is based on a prototype of the Grumman ADSF that flew sounding rocket and Space Shuttle experiments with Mn–MnBi alloys. The furnace uses a basic Bridgman furnace configuration. It been optimized for use in parabolic flight aircraft and has been fitted with a water spray interfacial quench device. The furnace has been employed extensively for KC–135 solidification experiments on metals and semiconductors over a 10-year period. It is also compatible with the DC–9 platform. Representative materials that have been investigated using this apparatus include metal alloys, plastics, superconductors, and metal matrix composites. From one to four samples, 0.5 cm in diameter and 6–15 cm in length, are processed per flight. Containment is typically alumina or quartz ampoules. Maximum operating temperature is 1500°C; temperature gradients of approximately 100°C/cm are achievable in metal alloy systems. The furnace can be translated at 0.1 to 100 cm/min. over a distance of 8 cm. The quench rate is typically 100°C/sec. Instrumentation supports acquisition of two sample temperatures, furnace temperature, cold end temperature, accelerations on three axes (mounted to furnace), and furnace position.

2. Isothermal Casting Furnace (ICF)
The ICF is designed for multidimensional solidification (bulk casting) during a single aircraft parabolic maneuver. The sample thermally soaks at a predetermined temperature for a specific length of time and is then quenched by a stream of helium gas during the low gravity period of the parabola. The furnace has been used for aircraft experiments for 10 years. Typical experiments include the testing of crucible wetting characteristics for immiscible alloys or semiconductors during solidification under low gravity conditions. Previously processed materials include iron-carbon alloys, immiscible metal alloys (e.g., aluminum-indium), and cadmium telluride. Sample dimensions are typically 0.9–1 cm in diameter by approximately 2 cm in length. The furnace operates over a range of temperatures from 100 to 1350°C. Quench rates range from 1°C/sec to 50°C/sec. Up to three sample temperatures can be recorded along with acceleration along three axes.

3. Quench Furnace With X-Ray
A Quench Furnace with X-Ray is also available for ground-based low-gravity research at LeRC. This three zone, end chill, directional solidification furnace with a water quench can reach a maximum temperature of 700°C. It was developed to study the solidification of metal samples during low-gravity testing in research aircraft. The liquid-gas and solid-liquid interfaces are recorded using x-ray scanning and high resolution CCD camera.

II. SPECIALIZED GROUND BASED REASEARCH CAPABILITIES

In addition to the specialized ground based microgravity capabilities such as drop tubes and drop towers, and parabolic aircraft, NASA is able to support selected Principal Investigators with state-of-the-art laboratory equipment, sample preparation facilities and computing support. These facilities are offered on an as available basis, through the Microgravity Science and Applications Division of the Marshall Space Flight Center, who have available trained personnel to assist all experiments.

A. MSFC ELECTROSTATIC LEVITATOR (ESL)

A new containerless electrostatic levitation research facility for materials and fluids is being established at MSFC, derived from a system donated by LORAL. The facility uses electrostatic forces to levitate specimens in a vacuum chamber, and then a high power infrared laser heats and melts these specimens. A 60 W YAG laser is available for metallic specimens and two 50 W CO_2 lasers are available for oxides and ceramic specimens. By isolating a material from all but its radiation environment, the disturbing influences of container walls and impurities are removed. The electrostatic forces will levitate a wide variety of materials: conductors, semiconductors, and insulators.

The specimen's position is controlled using a sophisticated three-dimensional digital feedback system manipulated through an intuitive and convenient computer interface. All of the controls over the specimen's motion and heating can be handled by a single user sitting at the control terminal.

Specimens are typically spheres, 2-3 mm in diameter. Once a specimen is levitated and melted, the ESL can apply a range of measurement techniques to measure the material's thermophysical properties, such as specific heat capacity, density, surface tension, viscosity, and optical emissivity, all as functions of temperature. At a given temperature, density is measured through analysis of a digitized silhouette image, and viscosity and surface tension are obtained from the frequency and rate of decay of shape oscillations.

B. HIGH MAGNETIC FIELD SOLIDIFICATION FACILITY

Built at MSFC, the High Magnetic Field Solidification Facility includes two 5 Tesla superconducting magnets each with a vertical, 25-cm diameter, room temperature bore. The use of a strong magnetic field can suppress fluid motion, thus simulating some of the effects of low gravity. By this means some important parameters can be determined which enable better use of the valuable and limited processing time in space. Resistance heated tubular furnaces capable of temperatures to 1200°C with bore diameters up to 2.5 cm are available and include thermal control and translation mechanisms. With appropriate inserts, the thermal environment of flight furnaces such as CGF and AADSF can be closely approximated. During FY96, ground based studies for two flight experiments, plus 2 other funded ground based studies have used the furnace. Prospective PI-specific modules would be considered for adaptation for this facility.

C. MAGNETIC DAMPING FURNACE

A prototype ground-based Magnetic Damping Furnace is expected to be a directional solidification Bridgman-Stockbarger furnace with or without magnetic damping. The major design characteristics of this device will include the application of a 0–0.2 Tesla magnetic field over the melt/solidification process if desired. The three zone furnace will operate at temperatures from 200 to 1175°C in the hot zone, 200–1200°C in the booster zone, and 150–950°C in the cold zone. A variable gradient zone of 0.5–5 cm length with a thermal gradient of up to 70°C/cm and an isothermality of ±0.1% is planned. The translating furnace will be capable of processing a sample from 12 to 20 cm in length with a diameter of up to 1.5 cm.

D. STEREO IMAGING VELOCIMETRY (SIV)

A system of hardware and software has been designed to allow acquisition of three-dimensional vectors describing flow simultaneously throughout an experimental volume. Used for ground-based and flight experiments, the quantitative results may be compared directly with numerical or analytical predictions of flow velocities. The system requires a transparent fluid seeded with particles large enough to be viewed as a full pixel on a video screen. Two synchronized orthogonal views provide the raw data. While generally used with light, the algorithms for velocity vectors could also be used with x-ray images of suspended particles. The SIV system has worked for sample volumes between eight cc's and two cubic meters. For experiments planned for the ISS, the Fluids and Combustion Facility will contain orthogonal video cameras which can record the data required for three-dimensional velocity analysis.

E. COMPUTATIONAL CAPABILITIES

NASA has the capability to provide the research community numerical modeling analysis (such as SINDA, HEATRAN, COSMOS, FIDAP) of material/fluid flows as influenced by thermal gradients, concentration gradients, surface tension, magnetic fields, gravitational acceleration, g-jitter and other driving forces. The emphasis is on physically based models giving quantitative flow descriptions. The facilities have commercial and specialized software operating in a workstation environment with access to mainframes.

F. X-RAY MICROSCOPE

This instrument is designed to view in situ solidification of thin, light samples with high resolution. The technique uses direct x-ray projection from a point source. The divergent beam passes through the sample. With a furnace permitting solidification to within a few mm of the x-ray source, in situ interfaces can be visualized at a resolution of 30 µm.

G. SPREADING RESISTANCE MEASUREMENT

A Solid State Measurements model 150 spreading resistance apparatus is available at MSFC. To use this instrument an investigator is expected to provide his/her own set of measurement probes.

H. OPTICAL AND ELECTRON OPTICAL MICROSCOPY LABORATORY

The equipment of a modern microscopy laboratory is available, including:

1. A Zeiss Axioplan 2 optical microscope equipped for reflection/transmission microscopy with Nomarski interference contrast, dark field, image processing, filar eyepieces for precise measurement, and automated and large stage capabilites. In addition and older Zeiss Ultraphot III optical microscope is with an infrared camera system is available.
2. A Zeiss scanning electron microscope, model DSM 960, equipped with a Link energy dispersive x-ray analysis system and beam controlling software. The collection of quantitative chemical analysis data can thus be automated. The system also includes an OPAL electron back scatter detector, which can be programmed to determine grain orientation over large sample areas. Other accessories include a cold stage and electron beam induced current imaging (EBIC).
3. A JEOL JXA 8900R electron microprobe analyzer equipped with three spectrometers for wavelength dispersive x-ray analysis, and a Noran energy dispersive x-ray system. Both of these systems permit quantitative light element determination. The microprobe is fitted with a large specimen stage.

All three of these systems are linked to the Internet.

I. X-RAY DIFFRACTION LABORATORY

X-ray diffraction capabilities include a Philips Materials Research Expert Diffractometer which operates on a Rigaku rotating anode x-ray generator.. This instrument is available for the measurement of rocking curves and for reciprocal lattice mapping. Other x-ray equipment available includes a Rigaku powder diffractometer, a Blake Industries Laue camera, and a Bede double axis diffractometer.

ACRONYM LISTING

ADSF	AUTOMATED DIRECTIONAL SOLIDIFICATION FURNACE
ATD	ADVANCED TECHNOLOGY DEVELOPMENT
CCD	CHARGE COUPLED DEVICE
ESL	ELECTROSTATIC LEVITATOR
FLUKA	FLUCTUATING KASKADE
GRC	GLENN RESEARCH CENTER
HETC	HIGH ENERGY TRANSPORT CODE
HZETRN	HIGH CHARGE, Z, AND ENERGY, E, TRANSPORT
ICF	ISOTHERMAL CASTING FURNACE
ISPR	INTERNATIONAL STANDARD PAYLOAD RACK
ISS	INTERNATIONAL SPACE STATION
JPL	JET PROPULSION LABORATORY
LLS	LASER LIGHT SCATTERING
MSFC	MARSHALL SPACE FLIGHT CENTER
MSG	MICROGRAVITY SCIENCE GLOVEBOX
MSRF	MATERIALS SCIENCE RESEARCH FACILITY
MSRR-1	FIRST MATERIALS SCIENCE RESEARCH RACK
MSL	MATERIALS SCIENCE LABORATORY
NASA	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
NRA	NASA RESEARCH ANNOUNCEMENT
OBPR	OFFICE OF BIOLOGICAL AND PHYSICAL RESEARCH
PI	PRINCIPAL INVESTIGATOR
PSD	PHYSICAL SCIENCES DIVISION
SIV	STEREO IMAGING VELOCIMETRY

INSTRUCTIONS FOR RESPONDING TO NASA RESEARCH ANNOUNCEMENTS (JANUARY 2000)

(a) General.

(1) Proposals received in response to a NASA Research Announcement (NRA) will be used only for evaluation purposes. NASA does not allow a proposal, the contents of which are not available without restriction from another source, or any unique ideas submitted in response to an NRA to be used as the basis of a solicitation or in negotiation with other organizations, nor is a pre-award synopsis published or individual proposals.

(2) A solicited proposal that results in a NASA award becomes part of the record of that transaction and may be available to the public on specific request; however, information or material that NASA and the awardee mutually agree to be of a privileged nature will be held in confidence to the extent permitted by law, including the Freedom of Information Act

(3) NRAs contain programmatic information and certain requirements which apply only to proposals prepared in response to that particular announcement. These instructions contain the general proposal preparation information which applies to responses to all NRAs.

(4) A contract, grant, cooperative agreement, or other agreement may be used to accomplish an effort funded in response to an NRA. NASA will determine the appropriate instrument. Contracts resulting from NRAs are subject to the Federal Acquisition Regulation and the NASA FAR Supplement. Any resultant grants or cooperative agreements will be awarded and administered in accordance with the NASA Grant and Cooperative Agreement Handbook (NPG 5800.1).

(5) NASA does not have mandatory forms or formats for responses to NRAs; however, it is requested that proposals conform to the guidelines in these instructions. NASA may accept proposals without discussion; hence, proposals should initially be as complete as possible and be submitted on the proposers' most favorable terms.

(6) To be considered for award, a submission must, at a minimum, present a specific project within the areas delineated by the NRA; contain sufficient technical and cost information to permit a meaningful evaluation; be signed by an official authorized to legally bind the submitting organization; not merely offer to perform standard services or to just provide computer facilities or services; and not significantly duplicate a more specific current or pending NASA solicitation.

(b) NRA-Specific Items. Several proposal submission items appear in the NRA itself: the unique NRA identifier; when to submit proposals; where to send proposals; number of copies required; and sources for more information. Items included in these instructions may be supplemented by the NRA.

(c) The following information is needed to permit consideration in an objective manner. NRAs will generally specify topics for which additional information or greater detail is desirable. Each proposal copy shall contain all submitted material, including a copy of the transmittal letter if it contains substantive information.

(1) Transmittal Letter or Prefatory Material.

(i) The legal name and address of the organization and specific division or campus identification if part of a larger organization;

(ii) A brief, scientifically valid project title intelligible to a scientifically literate reader and suitable for use in the public press;

(iii) Type of organization: e.g., profit, nonprofit, educational, small business, minority, women-owned, etc.;

(iv) Name and telephone number of the principal investigator and business personnel who may be contacted during evaluation or negotiation;

(v) Identification of other organizations that are currently evaluating a proposal for the same efforts;

(vi) Identification of the NRA, by number and title, to which the proposal is responding;

(vii) Dollar amount requested, desired starting date, and duration of project;

(viii) Date of submission; and

(ix) Signature of a responsible official or authorized representative of the organization, or any other person authorized to legally bind the organization (unless the signature appears on the proposal itself).

(2) Restriction on Use and Disclosure of Proposal Information. Information contained in proposals is used for evaluation purposes only. Offerors or quoters should, in order to maximize protection of trade secrets or other information that is confidential or privileged, place the following notice on the title page of the proposal and specify the information subject to the notice by inserting an appropriate identification in the notice. In any event, information contained in proposals will be protected to the extent permitted by law, but NASA assumes no liability for use and disclosure of information not made subject to the notice.

Notice: Restriction on Use and Disclosure of Proposal Information

The information (data) contained in [insert page numbers or other identification] of this proposal constitutes a trade secret and/or information that is commercial or financial and confidential or privileged. It is furnished to the Government in confidence with the understanding that it will not, without permission of the offeror, be used or disclosed other than for evaluation purposes; provided, however, that in the event a contract (or other agreement) is awarded on the basis of this proposal the Government shall have the right to use and disclose this information (data) to the extent provided in the contract (or other agreement). This restriction does not limit the Government's right to use or disclose this information (data) if obtained from another source without restriction.

(3) Abstract. Include a concise (200-300 word if not otherwise specified in the NRA) abstract describing the objective and the method of approach.

(4) Project Description.

(i) The main body of the proposal shall be a detailed statement of the work to be undertaken and should include objectives and expected significance; relation to the present state of knowledge; and relation to previous work done on the project and to related work in progress elsewhere. The statement should outline the plan of work, including the broad design of experiments to be undertaken and a description of experimental methods and procedures. The project description should address the evaluation factors in these instructions and any specific factors in the NRA. Any substantial collaboration with individuals not referred to in the budget or use of consultants should be described. Subcontracting significant portions of a research project is discouraged.

(ii) When it is expected that the effort will require more than one year, the proposal should cover the complete project to the extent that it can be reasonably anticipated. Principal emphasis should be on the first year of work, and the description should distinguish clearly between the first year's work and work planned for subsequent years.

(5) Management Approach. For large or complex efforts involving interactions among numerous individuals or other organizations, plans for distribution of responsibilities and arrangements for ensuring a coordinated effort should be described.

(6) Personnel. The principal investigator is responsible for supervision of the work and participates in the conduct of the research regardless of whether or not compensated under the award. A short biographical sketch of the principal investigator, a list of principal publications and any exceptional qualifications should be included. Omit social security number and other personal items which do not merit consideration in evaluation of the proposal. Give similar biographical

information on other senior professional personnel who will be directly associated with the project. Give the names and titles of any other scientists and technical personnel associated substantially with the project in an advisory capacity. Universities should list the approximate number of students or other assistants, together with information as to their level of academic attainment. Any special industry-university cooperative arrangements should be described.

(7) Facilities and Equipment.

- (i) Describe available facilities and major items of equipment especially adapted or suited to the proposed project, and any additional major equipment that will be required. Identify any Government-owned facilities, industrial plant equipment, or special tooling that are proposed for use. Include evidence of its availability and the cognizant Government points of contact.
- (ii) Before requesting a major item of capital equipment, the proposer should determine if sharing or loan of equipment already within the organization is a feasible alternative. Where such arrangements cannot be made, the proposal should so state. The need for items that typically can be used for research and non-research purposes should be explained.

(8) Proposed Costs (U.S. Proposals Only).

- (i) Proposals should contain cost and technical parts in one volume: do not use separate "confidential" salary pages. As applicable, include separate cost estimates for salaries and wages; fringe benefits; equipment; expendable materials and supplies; services; domestic and foreign travel; ADP expenses; publication or page charges; consultants; subcontracts; other miscellaneous identifiable direct costs; and indirect costs. List salaries and wages in appropriate organizational categories (e.g., principal investigator, other scientific and engineering professionals, graduate students, research assistants, and technicians and other non-professional personnel). Estimate all staffing data in terms of staff-months or fractions of full-time.
- (ii) Explanatory notes should accompany the cost proposal to provide identification and estimated cost of major capital equipment items to be acquired; purpose and estimated number and lengths of trips planned; basis for indirect cost computation (including date of most recent negotiation and cognizant agency); and clarification of other items in the cost proposal that are not self-evident. List estimated expenses as yearly requirements by major work phases.
- (iii) Allowable costs are governed by FAR Part 31 and the NASA FAR Supplement Part 1831 (and OMB Circulars A-21 for educational institutions and A-122 for nonprofit organizations).
- (iv) Use of NASA funds--NASA funding may not be used for foreign research efforts at any level, whether as a collaborator or a subcontract. The direct purchase of supplies and/or services, which do not constitute research, from non-U.S. sources by U.S. award recipients is permitted. Additionally, in accordance with the National Space Transportation Policy, use of a non-U.S. manufactured launch vehicle is permitted only on a no-exchange-of-funds basis.

(9) Security. Proposals should not contain security-classified material. If the research requires access to or may generate security-classified information, the submitter will be required to comply with Government security regulations.

(10) Current Support. For other current projects being conducted by the principal investigator, provide title of project, sponsoring agency, and ending date.

(11) Special Matters.

- (i) Include any required statements of environmental impact of the research, human subject or animal care provisions, conflict of interest, or on such other topics as may be required by the nature of the effort and current statutes, executive orders, or other current Government-wide guidelines.
- (ii) Proposers should include a brief description of the organization, its facilities, and previous work experience in the field of the proposal. Identify the cognizant Government audit agency, inspection agency, and administrative contracting

officer, when applicable.

(d) Renewal Proposals.

(1) Renewal proposals for existing awards will be considered in the same manner as proposals for new endeavors. A renewal proposal should not repeat all of the information that was in the original proposal. The renewal proposal should refer to its predecessor, update the parts that are no longer current, and indicate what elements of the research are expected to be covered during the period for which support is desired. A description of any significant findings since the most recent progress report should be included. The renewal proposal should treat, in reasonable detail, the plans for the next period, contain a cost estimate, and otherwise adhere to these instructions.

(2) NASA may renew an effort either through amendment of an existing contract or by a new award.

(e) Length. Unless otherwise specified in the NRA, effort should be made to keep proposals as brief as possible, concentrating on substantive material. Few proposals need exceed 15-20 pages. Necessary detailed information, such as reprints, should be included as attachments. A complete set of attachments is necessary for each copy of the proposal. As proposals are not returned, avoid use of “one-of-a-kind” attachments.

(f) Joint Proposals.

(1) Where multiple organizations are involved, the proposal may be submitted by only one of them. It should clearly describe the role to be played by the other organizations and indicate the legal and managerial arrangements contemplated. In other instances, simultaneous submission of related proposals from each organization might be appropriate, in which case parallel awards would be made.

(2) Where a project of a cooperative nature with NASA is contemplated, describe the contributions expected from any participating NASA investigator and agency facilities or equipment which may be required. The proposal must be confined only to that which the proposing organization can commit itself. "Joint" proposals which specify the internal arrangements NASA will actually make are not acceptable as a means of establishing an agency commitment.

(g) Late Proposals. Proposals or proposal modifications received after the latest date specified for receipt may be considered if a significant reduction in cost to the Government is probable or if there are significant technical advantages, as compared with proposals previously received.

(h) Withdrawal. Proposals may be withdrawn by the proposer at any time before award. Offerors are requested to notify NASA if the proposal is funded by another organization or of other changed circumstances which dictate termination of evaluation.

(i) Evaluation Factors.

(1) Unless otherwise specified in the NRA, the principal elements (of approximately equal weight) considered in evaluating a proposal are its relevance to NASA’s objectives, intrinsic merit, and cost.

(2) Evaluation of a proposal's relevance to NASA’s objectives includes the consideration of the potential contribution of the effort to NASA's mission.

(3) Evaluation of its intrinsic merit includes the consideration of the following factors of equal importance:

(i) Overall scientific or technical merit of the proposal or unique and innovative methods, approaches, or concepts demonstrated by the proposal.

(ii) Offeror's capabilities, related experience, facilities, techniques, or unique combinations of these which are integral factors for achieving the proposal objectives.

(iii) The qualifications, capabilities, and experience of the proposed principal investigator, team leader, or key personnel critical in achieving the proposal objectives.

(iv) Overall standing among similar proposals and/or evaluation against the state-of-the-art.

(4) Evaluation of the cost of a proposed effort may include the realism and reasonableness of the proposed cost and available funds.

(j) Evaluation Techniques. Selection decisions will be made following peer and/or scientific review of the proposals. Several evaluation techniques are regularly used within NASA. In all cases proposals are subject to scientific review by discipline specialists in the area of the proposal. Some proposals are reviewed entirely in-house, others are evaluated by a combination of in-house and selected external reviewers, while yet others are subject to the full external peer review technique (with due regard for conflict-of-interest and protection of proposal information), such as by mail or through assembled panels. The final decisions are made by a NASA selecting official. A proposal which is scientifically and programmatically meritorious, but not selected for award during its initial review, may be included in subsequent reviews unless the proposer requests otherwise.

(k) Selection for Award.

(1) When a proposal is not selected for award, the proposer will be notified. NASA will explain generally why the proposal was not selected. Proposers desiring additional information may contact the selecting official who will arrange a debriefing.

(2) When a proposal is selected for award, negotiation and award will be handled by the procurement office in the funding installation. The proposal is used as the basis for negotiation. The contracting officer may request certain business data and may forward a model award instrument and other information pertinent to negotiation.

(l) Additional Guidelines Applicable to Foreign Proposals and Proposals Including Foreign Participation.

(1) NASA welcomes proposals from outside the U.S. However, foreign entities are generally not eligible for funding from NASA. Therefore, unless otherwise noted in the NRA, proposals from foreign entities should not include a cost plan unless the proposal involves collaboration with a U.S. institution, in which case a cost plan for only the participation of the U.S. entity must be included. Proposals from foreign entities and proposals from U.S. entities that include foreign participation must be endorsed by the respective government agency or funding/sponsoring institution in the country from which the foreign entity is proposing. Such endorsement should indicate that the proposal merits careful consideration by NASA, and if the proposal is selected, sufficient funds will be made available to undertake the activity as proposed.

(2) All foreign proposals must be typewritten in English and comply with all other submission requirements stated in the NRA. All foreign proposals will undergo the same evaluation and selection process as those originating in the U.S. All proposals must be received before the established closing date. Those received after the closing date will be treated in accordance with paragraph (g) of this provision. Sponsoring foreign government agencies or funding institutions may, in exceptional situations, forward a proposal without endorsement if endorsement is not possible before the announced closing date. In such cases, the NASA sponsoring office should be advised when a decision on endorsement can be expected.

(3) Successful and unsuccessful foreign entities will be contacted directly by the NASA sponsoring office. Copies of these letters will be sent to the foreign sponsor. Should a foreign proposal or a U.S. proposal with foreign participation be selected, NASA's Office of External Relations will arrange with the foreign sponsor for the proposed participation on a no-exchange-

of-funds basis, in which NASA and the non-U.S. sponsoring agency or funding institution will each bear the cost of discharging their respective responsibilities.

(4) Depending on the nature and extent of the proposed cooperation, these arrangements may entail:

(i) An exchange of letters between NASA and the foreign sponsor; or

(ii) A formal Agency-to-Agency Memorandum of Understanding (MOU).

(m) Cancellation of NRA. NASA reserves the right to make no awards under this NRA and to cancel this NRA. NASA assumes no liability for canceling the NRA or for anyone's failure to receive actual notice of cancellation.

Appendix D
NRA 01-OBPR-05

NASA RESEARCH ANNOUNCEMENT (NRA) SCHEDULE

MICROGRAVITY MATERIALS SCIENCE: RESEARCH AND FLIGHT EXPERIMENT OPPORTUNITIES

All proposals submitted in response to this Announcement are due on the date and at the address given below by the close of business (4:30 PM EST). NASA reserves the right to consider proposals received after this deadline if such action is judged to be in the interest of the U.S. Government. A complete schedule of the review of the proposals is given below:

NRA Release Date: ....August 24, 2001

Notice of Intent Due: ....September 25, 2001

Proposal Due: ....November 27, 2001

Submit Proposal to:

Dr. Michael J. Wargo
c/o NASA Peer Review Services
Subject: NASA Research Proposal (NRA-01-OBPR-05)
500 E Street, S.W., Suite 200
Washington, D.C. 20024
Telephone number for delivery services: (202) 479-9030

Final Selections: ....May, 2002

Funding commences: .... August - October, 2002
(dependent upon actual selection and procurement process)

Appendix E
NRA 01-OBPR-05

Instructions for Notice of Intent and Proposal Submission

ALL APPLICANTS TO THIS RESEARCH ANNOUNCEMENT USE "*SYS-EYFUS*," THE NASA INTERNET-BASED PROPOSAL MANAGEMENT SYSTEM TO SUBMIT A NON-BINDING NOTICE OF INTENT AND THE REQUIRED NEW PROPOSAL SUMMARY INFORMATION BY FOLLOWING THE DEATAILED INSTRUCTIONS BELOW.

A. **To obtain the required SYS-EYFUS login username and password**, go to:

http://proposals.hq.nasa.gov/forgotpassword/forgotlogin.cfm

Type your first and last name to search the SYS-EYFUS database.

- If your name appears in the result set, select the corresponding radio button and click on **Continue**. This will trigger the system to send an automatic email message with your username and password to your email address as listed in our database.
- If your name does not appear on the result set, select the radio button **"None of the Above"** and click on **Continue**.. This will allow you to add yourself as a NEW USER to the system. The system will prompt you to choose a username and a password towards the end of the new user addition procedure. This username and password combination allows you to access the system and to submit Notices of Intent and Proposal Summaries.

B. To submit a Notice of Intent (NOI):

- Go to the **SYS-EYFUS Home-page:** *http://proposals.hq.nasa.gov*
- Click on **Login** in the **Proposal Links Section** on the left side of the page.
- Insert your username and password and click on **Continue.**
- Click on **New Notice of Intent** in the **Options** screen. The Division Specific Opportunities screen will appear.
- Highlight **Physical Sciences** in the selection window and click on **Continue.**
- Click on **01-OBPR-05**, and then click on **Continue**. The **Notice of Intent Submission Form** will appear.
- Fill in all the fields, and select a theme from the pop-up lists. All fields are required.
- Click on **Submit NOI Page**. The Team Member Page will appear.
- Add (or remove) team members as follows.
  - Co-Investigators. (IMPORTANT! Co-investigators, who are not in the SYS-EYFUS database, must register themselves as new users in SYS-EYFUS.) To add a co-investigator, highlight the COI option on the selection list, type in first and last name of the co-investigator, and click on **Search.** When the result set appears, choose the radio button by the co-investigator's name and click on **ADD**.. Repeat this process for each co-investigator. After all co-investigators have been added, click on **Continue**.

- o Other Participating Organizations (*e.g*., use of specific facilities). An individual point of contact must be chosen for each other participating organization. To add a participating organization point of contact, highlight the **Collaborator** option and proceed as described for co-investigators above.

- Click on **Resubmit NOI Page** and then on **Continue**.

C. To submit New Proposal Summary Information:

- Go to the **SYS-EYFUS Home-page:** *http://proposals.hq.nasa.gov*
- Click on **Login** in the **Proposal Links Section** on the left side of the page.
- Insert your username and password and click on **Continue.**
- Click on **New Proposal Cover Page** in the **Options** screen. The New Proposals Cover Page screen will appear.
- Click again on **New Proposal Cover Page**. The Division Specific Opportunities screen will appear.
- Highlight **Physical Sciences** in the selection window and click on **Continue**.
- Click on **NRA-01-OBPR-05**, and then click on **Continue**. The Proposal Cover Page Form will appear.
- Fill in all the fields, and select a theme from the pop-up lists. All fields are required.
- Click on **Continue**. The Team Member Page will appear.
- To add (or remove) a team member, highlight the **Team Member ROLE** on the selection list, type in first and last name of the team member, and click on **Search**. When the result set appears, choose the radio button by the team member's name and click on **ADD**. Repeat this process until all required team members have been added. The following team members are required: Co-investigators, Authorizing Official, "Contact In Case of Award" and "Point of Contact for Other Participating Organization (added as **Collaborator). IMPORTANT! Team members who are not in the SYS-EYFUS database must register themselves as new users in SYS-EYFUS.**
- After all team members have been added, click on **Continue**. The Proposal Options Page will appear.
- Click on the **Budget** button. Fill in the budget form with project costs and click on **Continue**.. The Proposal Budget Review Page will appear. Click on **Continue** if the information is correct.
- On the next screen click the **Show/Print** button. The "**Proposal Information Item List**" page will appear. Click **Show** to review your **Proposal Cover Page**. Print the cover page once you have reviewed the information for accuracy. This cover page must be signed by both the Principal Investigator and the Authorizing Official and attached to the front of your proposal (original and all copies) for submission to NASA.

One (1) signed original and fifteen (15) copies of the proposal must be submitted to NASA by 4:00 PM of *November 27*, 2001.

CERTIFICATION REGARDING DEBARMENT, SUSPENSION, AND OTHER RESPONSIBILITY MATTERS *PRIMARY COVERED TRANSACTIONS*

This certification is required by the regulations implementing Executive Order 12549, Debarment and Suspension, 14 CFR Part 1269.

A. The applicant certifies that it and its principals:

(a) Are not presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency;

(b) Have not within a three-year period preceding this application been convicted or had a civil judgement rendered against them for commission of fraud or a criminal offense in connection with obtaining, attempting to obtain, or performing a public (Federal, State, or Local) transaction or contract under a public transaction; violation of Federal or State antitrust statutes or commission of embezzlement, theft, forgery, bribery, falsification or destruction of records, making false statements, or receiving stolen property;

(c) Are not presently indicted for or otherwise criminally or civilly charged by a government entity (Federal, State, or Local) with commission of any of the offenses enumerated in paragraph A.(b) of this certification; and

(d) Have not within a three-year period preceding this application/proposal had one or more public transactions (Federal, State, or Local) terminated for cause or default; and

B. Where the applicant is unable to certify to any of the statements in this certification, he or she shall attach an explanation to this application.

C. Certification Regarding Debarment, Suspension, Ineligibility and Voluntary Exclusion - Lowered Tier Covered Transactions (Subgrants or Subcontracts)

(a) The prospective lower tier participant certifies, by submission of this proposal, that neither it nor its principles is presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from participation in this transaction by any federal department of agency.

(b) Where the prospective lower tier participant is unable to certify to any of the statements in this certification, such prospective participant shall attach an explanation to this proposal.

This page has been included for your information. Do not submit this page with your application. A signature on the Proposal Cover Page satisfies the requirement of compliance with the provisions, rules, and stipulations described on this page.

CERTIFICATION REGARDING LOBBYING

As required by S 1352 Title 31 of the U.S. Code for persons entering into a grant or cooperative agreement over $100,000, the applicant certifies that:

(a) No Federal appropriated funds have been paid or will be paid by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, in connection with making of any Federal grant, the entering into of any cooperative, and the extension, continuation, renewal, amendment, or modification of any Federal grant or cooperative agreement;

(b) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting an officer or employee of any agency, Member of Congress, an or an employee of a Member of Congress in connection with this Federal grant or cooperative agreement, the undersigned shall complete Standard Form - LLL, "Disclosure Form to Report Lobbying," in accordance with its instructions.

(c) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers (including subgrants, contracts under grants and cooperative agreements, and subcontracts), and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by S1352, title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

This page has been included for your information. Do not submit this page with your application. A signature on the Proposal Cover Page satisfies the requirement of compliance with the provisions, rules, and stipulations described on this page.

CERTIFICATION OF COMPLIANCE WITH THE NASA REGULATIONS PURSUANT TO NONDISCRIMINATION IN FEDERALLY ASSISTED PROGRAMS

The (Institution, corporation, firm, or other organization on whose behalf this assurance is signed, hereinafter called "Applicant") hereby agrees that it will comply with Title VI of the Civil Rights Act of 1964 (P.L. 88-352), Title IX of the Education Amendments of 1962 (20 U.S. 1680 et seq.), Section 504 of the Rehabilitation Act of 1973, as amended (29 U.S. 794), and the Age Discrimination Act of 1975 (42 U.S. 16101 et seq.), and all requirements imposed by or pursuant to the Regulation of the National Aeronautics and Space Administration (14 CFR Part 1250) (hereinafter called "NASA") issued pursuant to these laws, to the end that in accordance with these laws and regulations, no person in the United States shall, on the basis of race, color, national origin, sex, handicapped condition, or age be excluded from participating in, be denied the benefits of, or be otherwise subjected to discrimination under any program or activity for which the Applicant receives federal financial assistance from NASA; and hereby give assurance that it will immediately take any measure necessary to effectuate this agreement.

If any real property or structure thereon is provided or improved with the aid of federal financial assistance extended to the Applicant by NASA, this assurance shall obligate the Applicant, or in the case of any transfer of such property, any transferee, for the period during which the real property or structure is used for a purpose for which the federal financial assistance is extended or for another purpose involving the provision of similar services or benefits. If any personal property is so provided, this assurance shall obligate the Applicant for the period during which the federal financial assistance is extended to it by NASA.

This assurance is given in consideration of and for the purpose of obtaining any and all federal grants, loans, contracts, property, discounts, or other federal financial assistance extended after the date hereof to the Applicant by NASA, including installment payments after such date on account of applications for federal financial assistance which were approved before such date. The Applicant recognized and agrees that such federal financial assistance will be extended in reliance on the representations and agreements made in this assurance, and the United States shall have the right to seek judicial enforcement of this assurance. His assurance is binding on the Applicant, its successors, transferees, and assignees, and the person or persons whose signatures appear below are authorized to sign on behalf of the Applicant.

This page has been included for your information. Do not submit this page with your application. A signature on the Proposal Cover Page satisfies the requirement of compliance with the provisions, rules, and stipulations described on this page.